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PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy.

NEW SERIES.

No. 37.

217493
18. 10. 21

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

31st MARCH, 1920.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY, MELBOURNE.

Australasian Institute of Mining and Metallurgy.

LIST OF OFFICERS, 1920.

President:

R. W. CHAPMAN, S.A.

Vice-Presidents:

D. B. WATERS, N.Z.
GEORGE C. KLUG, W.A.
COLIN FRASER, S.A.

Councillors:

ROBERT C. STICHT	Tasmania
A. A. BOYD	Queensland
W. E. WAINWRIGHT	New South Wales
JAMES HEBBARD	New South Wales
G. H. BLAKEMORE	New South Wales
JAMES HORSBURGH	Queensland
H. W. GEPP	Tasmania
JOHN M. BRIDGE	New South Wales
E. G. BANKS	New Zealand
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JOHN W. MOULE	Queensland
G. D. DELPRAT	New South Wales
RICHARD HAMILTON	Western Australia
A. S. KENYON	Victoria
GEO H. BROOME	Victoria
GEORGE WEIR	New South Wales
J. W. SUTHERLAND	Western Australia

Secretary:

D. L. STIRLING, Melbourne, Vic.

LOCAL CORRESPONDENTS:

South Australia	R. W. CHAPMAN, Adelaide.
New South Wales	F. DANVERS POWER, Sydney.
Western Australia	F. W. R. GODDEN, Hampton Plains.
New Zealand	D. B. WATERS, Dunedin.
Tasmania	RUSSELL M. MURRAY, Mount Lyell.
North Queensland	MURRAY RUSSELL, Brisbane.

BRANCH SECRETARIES:

Kalgoorlie	F. W. R. GODDEN, Ivanhoe Gold Corporation, Boulder, W.A.
Broken Hill	C. H. J. CLAYTON, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. PATTERSON, Mount Morgan, Q.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 QUEEN STREET, MELBOURNE, VICTORIA.

Institute Matters.

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MINUTES OF MEETINGS.

OF THE INSTITUTE.

ANNUAL MEETING.

MELBOURNE, 30TH JANUARY, 1920.

IN THE INSTITUTE ROOMS, 48 QUEEN STREET, AT 1 P.M.

Mr. H. Herman (member of Council) occupied the chair.

The Secretary read the notice convening the meeting.

Minutes of the Special General Meeting and the First Ordinary Meeting, 1920, held in October, were read and confirmed.

The Report of the Council and Balance-Sheet for 1919 were submitted and adopted.

As the nominations to fill the vacancies created by the annual retirement of office-bearers were not in excess of the vacancies, the Chairman declared the following elected :—

President - - R. W. Chapman.
Vice-President - Colin Fraser.
Council - - Robert C. Sticht.
A. A. Boyd.
W. E. Wainwright.
G. H. Blakemore.
James Hebbard.
James Horsburgh.
H. W. Gepp.

The meeting then closed.

Report of Council for 1919.

TO THE MEMBERS.

The Council has pleasure in submitting the following summarized report of the Proceedings of the Institute for the past year.

Membership now totals 585, made up as follows: — Life Members, 4; Members, 372; Associate Members, 149; Students, 60. Six Members, 7 Associate Members, and 1 Student were admitted during the year; 3 members resigned, 4 died, and reports have come to hand that 7 more members were killed on active service during the war. Four Associate Members were transferred to the grade of Member. The total membership, therefore, remains the same as last year.

The Council has, with sincere regret, to report the loss the Institute has sustained by the death of four prominent members, viz. :—F. H. Evans, Manager of the Sulphide Corporation's works at Cockle Creek, N.S.W. ; H. W. Ferd. Kayser (Foundation Member), formerly Manager of the Mount Bischoff Co., Tasmania ; H. R. Hancock (Foundation Member), for 28 years superintendent of operations at the Wallaroo and Moonta mines, S.A. ; and Dr. Rossiter W. Raymond (Honorary Member), Secretary of the American Institute of Mining and Metallurgical Engineers. Belated reports have also been received of the deaths of the following members whilst on active service, viz. :—Willoughby G. Bell (Life Member), late of the Crœsus South G.M. Co., Kalgoorlie, W.A. ; Francis P. Bray, who, prior to the war, was engaged in mining operations in West Africa ; H. S. Warde, formerly Mining Inspector, Rockhampton, Queensland ; W. P. Avery, of the Klong Sa mine, Tammarat Mining Syndicate, Bandon, Siam ; Andrew Getty, late Assistant Surveyor, Ivanhoe Gold Corporation, Boulder, W.A. ; W. H. A. MacDonnell, of the Charters Towers School of Mines ; and Kenneth Aubrey Mickle, who, at the outbreak of the war, was chief chemist at the Burma Mines Ltd., Upper Burma. Obituary notices concerning these members appeared in the Proceedings.

Resignations as follow were accepted :—Messrs. Joseph Grimmond, W. B. Blyth, and W. A. MacLeod.

Four meetings of the Institute were held at Melbourne during the year—the Annual Meeting on 31st January, Special General Meetings on 6th June and 27th and 28th October, and the First Ordinary Meeting on 29th October. Minutes of these meetings were published in Proceedings Nos. 33, 34, and 36. No definite announcement can yet be made in regard to the locality of the First Ordinary Meeting, 1920, but it is hoped that the projected visit to Port Pirie will be arranged.

Committees as follow were appointed during the year :—An Executive Committee, a Finance Committee, a Publication and

Education Committee, a Branches Committee, and a Mining Managers' Certificates Committee.

By ballot of members, taken on 6th June, it was decided that the name of the Institute should be altered to "The Australasian Institute of Mining and Metallurgy." The new title is much more comprehensive and in keeping with the aims and objects of the Institute.

The Honour Roll (pp. xi, xii), containing the names of those members who were on active service during the war, is now fairly complete, but it is possible that some names are still omitted. The Council would, therefore, be glad to receive any information to complete the list, also particulars of honours conferred or of changes in rank. Names of members who were engaged in war work, though not actually "on active service," are also desired. The honour roll contains 127 names. This is a matter of pride to the Institute, more especially so as such a large proportion won decorations for gallant and distinguished service. The Special Order issued by the Commander-in-Chief of the British Forces, published in Proceedings No. 32, is a very high compliment to the splendid services rendered by the units, so many of which were officered by members of the Institute.

Papers published in the Proceedings during the year included :—"Tapping Water by Diamond Drill Holes," by Edmund B. Dow; "Isometric Mine Plans," by H. Edward Clayton; "Ore Treatment, Plant and Treatment Operations at the Edna May Gold Mining Co., N.L., Westonia, W.A.," by Mr. T. Williams; "Notes on Cornish Tin Mining," by the late W. F. M'Bryde Broun; "Notes on the S. and M. Mine and on Treatment of Bismuth, Tin, and Wolfram Ores," by Wm. E. Hitchcock and J. R. Pound; "What is the Matter with Australian Mining?" (with discussion) by F. Danvers Power; "Underground Sampling," by Walter G. A. Smith; "Froth Flotation at Broken Hill" (with discussion), by C. C. Freeman.

The following papers have been approved for publication, and will appear in the March issue of Proceedings :—"Notes on the

Work of an Australian Tunnelling Company in France," by Oliver H. Woodward; "Some Controlling Factors in Flotation" (with discussion), by Ralph D. Nevett.

The Council has decided that representatives of the technical press be permitted to peruse, in the Institute rooms, the MSS. of papers presented to the Institute and approved for publication in the Proceedings, and to publish a summary thereof, subject to the consent of the author. It has also been decided that, unless otherwise stipulated by authors of papers, degrees be published after authors' names.

The Secretary, Department of Defence, Commonwealth of Australia, in November last invited the Institute to undertake the writing and publication of a book of 250–300 pages on the offensive and defensive work underground during the Great War. The Council accepted the invitation, and appointed a committee to take the matter in hand. The committee will, in the first place, ascertain if a desire exists among the members and mining companies for such an important record to be written. It would appoint a writer at a salary, undertake the collection of subscriptions to cover the cost, also the distribution of the book. The Government would provide clerical assistance, the necessary maps and diagrams, access to all records, and space to work upon them. This work would be of great historic value, especially to members of the Institute. Members will be requested later to indicate whether they desire to take copies of the work when finished.

The "A. T. Danks Prize, 1918," for the best paper contributed by a student taking part in the 1918 excursion has been awarded to Mr. Theodore W. Tobe, of the Melbourne University.

During the year Mr. J. W. Sutherland, past President, generously placed in the hands of the Council the sum of fifty guineas, to be used at its discretion for the purpose of encouraging students in mining and metallurgy by means of prizes or medals or to help forward any of the other objects of the Institute. The Publication and Education Committee has been deputed to give effect to Mr. Sutherland's wishes.

The Institute is also indebted to the Broken Hill Mining Managers' Association for the very practical way in which it has encouraged the writing of papers on technical subjects. This Association has donated the sum of £100 to the Broken Hill branch for four prizes of £25 each for papers on (1) wet concentration, (2) flotation ; the selection of subjects for prizes 3 and 4 has been left to the discretion of the branch.

The Council desires to place on record its appreciation of the donations above-mentioned.

The Council is pleased to report that the funds donated by the principal Australian base-metal mining companies for providing bursaries and scholarships for mining students have been sufficiently augmented to allow of the extension of the system to the Sydney, Brisbane, and Hobart Universities. Mr. Wm. Poole and Mr. H. W. Gepp have been appointed to represent the Institute on the selection committees representing the Sydney and Hobart Universities respectively. The nomination of an Institute representative to the selection committee of the Brisbane University will shortly be made.

The Employment Register, inaugurated in 1917, has been of considerable assistance in securing positions for members, and in this matter mining companies have readily co-operated with the Institute. Members desiring engagement should forward to the Secretary, for filing, full particulars of their qualifications and experience, copies of references, and the class of engagement they are anxious to secure. It is expected that the system will be considerably extended during the coming year.

As recommended at the First Ordinary Meeting, 1919, a committee has been appointed to prepare a statement on the subject of certification of Mine Managers. The recommendations when complete will be forwarded to the various Departments of Mines.

The proposal that the Institute should lend its support to the movement for the adoption by the English-speaking peoples of the decimal or metric system in place of the system of weights and measures was discussed by the Council and approved. It was recognized, however, that a comprehensive change over to the metric system would involve a large capital expenditure and be very far-reaching in its incidence, and a suggestion was made that the matter be referred to a representative British Royal Commission for investigation and recommendation. It has been shown that 70 per cent. of all nations have discarded the arbitrary standards of weights and measures and have made the metric system obligatory. A recommendation on this matter will be made by the Council during the ensuing year.

Consideration was given by the Council in October last to a proposed amendment of the *Local Government Act*, New South Wales, affecting the taxation of metalliferous mines. After representations were made, the clause objected to was further amended, to the satisfaction of the Council.

The Institute of Science and Industry has been approached with the view to ensuring that the mining industry is represented on the Advisory Councils of each State and on Standardization Committees.

With the termination of the war members were invited to assist in the establishment of local committees in each capital city and in mining and metallurgical centres where branches are not already in existence. As a result a local committee has been formed in Sydney, consisting of Messrs. A. A. Atkinson, G. H. Blakemore, F. A. Eastaugh, Wm. Poole, F. Danvers Power, A. E. Savage, and J. D. Audley Smith. The Council trusts that during the ensuing year members will exercise their privileges in this matter and so assist in extending the usefulness and influence of the Institute. These local committees will form the nucleus of branches under the new constitution.

As anticipated, the proposal that the Australasian Institute of Mining and Metallurgy should become a branch of the Institution of Engineers of Australia was rejected by members by an overwhelming majority; but, as intimated at the commencement of the discussion on this question, the Council would welcome a scheme of federation with the new Institute when its establishment is satisfactorily completed.

Members have been kept fully informed, through the medium of the Proceedings and the various circulars issued during the year, of developments in the matter of the extension of the scope and activities of the Institute; but the issue is of such great importance that the Council urges members to thoroughly realize by a careful study of the memorandum and articles of association recently issued and discussed at the special meeting in October, what this movement means. The proposed new constitution was very carefully drafted, and certain important improvements suggested at the special meeting. The draft showing these amendments will shortly be posted to members for their final suggestions, and the final draft will then be submitted for ballot. With the acceptance of the constitution the necessary steps towards incorporation will immediately be taken. Apart from the most important matter of the extension of scope, the Council desires, at this stage, to especially direct the attentions of members to the following important points which the adoption of the new constitution involves:—

(1) A still further stiffening of the requirements regarding admission to the Institute.

(2) A strong movement to secure by the Institute or other authority the establishment of a register of mining engineers and metallurgists duly qualified to act as such.

(3) All Members, Associate Members, and Students of the present unincorporated Institute automatically become members, etc., under the new constitution *on payment of arrears of subscription* (*if any*). The Council trusts, however, that, under this clause, no exclusions will be necessary; but this rests entirely with the members themselves.

HONOUR ROLL.

Aarons, J. Boyd, Capt.
Adcock, Garnet I., Capt.
Alexander, E. S.
Anderson, A. F. S.
Anderson, W. T., Lieut.
Avery, Wm. P. (killed in action).
Bayly, Colin (killed in action).
Banks, C. A., Capt.
Barber, C. S., M.C.
Bennet, V. C., Lieut.
Berriman, R. V.
Best, G. H. T., M.C.
Bell, W. G. (killed in action).
Bell, J. Mackintosh, Lt.-Col.
Bloom, Leo.
Blunden, L. E.
Bray, F. P., Major (killed in action).
Brown, H. Wheeler.
Bullen, G. L.
Burbridge, Percy.
Campbell, A. G., Capt., D.S.O.
Casey, R. G., Major, D.S.O.
Carless, Noel, Staff-Sergeant.
Carroll, H. H., Capt., M.C.
Connor, J. L. (killed in action).
Coulter, Leslie J., Major, D.S.O. (killed in action).
Cowles, Richard.
Clayton, C. H. J., Lieut.
Cleland, W. L.
Davies, H. Warlow, Lieut.
Dean, Harry M.
Dempster, G. C.
Donaldson, R. J., Maj., D.S.O.
Dow, J., Lieut.
Drain, P. J.
Dubois, A. J., Capt.
Dunstan, Basil.
Eastaugh, F. A.
Elford, C.
Ford, Norman (killed in action).
Foster, Donald.
Foxall, J. S.
Fraser, Donald L., Lieut.
Fraser, E. H., Capt.
Finlayson, R. J. Stanley.
Gartrell, W. H., Lieut.
Gabriel, G. E., Lieut., M.M.
Grieve, W. H.
Goode, K. K.
Grut, L. de Jersey, Capt., M.C.
Hargraves, E. P., Lieut.
Hammel, H. E., Lieut. (killed in action).
Herbertson, R. C. (killed in action).
Hogarth, A. M. (killed in action).
Holder, E. M.
Hooper, F. H.
Horsley, Ralf D.
Hunter, Stanley B., Capt.
Hughes, Eric W.
Irvine, C. L.
Kelly, M. B. H., Capt., Croix de Guerre.
Jowett, A. C., Capt.
Junner, Norman R., Major, M.C.
Kelly, A. H.
Kerr, F. T.
Key, J. F.

Honour Roll—*continued.*

Kneebone, C. S., M.M.
Lakeland, Wm. J., Major.
Lewis, Keith B., Lieut.
Marks, D. G., Lieut.-Col.
Mawdsley, W. H.
Marryatt, Cyril S.
MacDonnell, W. H. A. (killed in action).
MacKenzie, D. C., Lieut.
M'Bride, W. J., Capt., M.C.
M'Bryde, Jas. (killed in action).
M'Callum, N. S. Kellie.
M'Padden, J. C.
Mickle, Kenneth A., Capt., D.S.O. (died of gas).
Millett, Bert.
Moore, R. Ingram, Capt., D.S.O. (killed in action).
Morris, A. C.
Mulligan, E. N., Major.
Moore, K. Byron, Lieut.
Nicholas, F. H., M.M.
Newman, J. Malcolm.
Osborne, G. W.
Pearson, H. F.
Peat, James (killed in action).
Peberdy, J. R.
Pethebridge, H. S., Lieut., M.C.
Plant, G. H. D.
Rabling, Harold.
Roberts, W. J.
Rose, W. J., Capt., M.C.
Ross, C. N.
Rutherford, A. R
Rutherford, T. W. L., Capt., M.C.
Rae, Cecil, Lieut.-Col.
Sayer, W. T. (killed in action).
Seale, H. V.
Shaw, J. B., Lieut., M.C.
Skerritt, A. W.
Smith, H. Hardy.
Smith, R. S.
Smith, W. F., Lieut. (killed in action).
Smith, E.
Southon, R. D., M.C.
Sweet, O. G.
Tandy, A. E. (killed in action).
Taylor, A. S.
Taylor, E. Foulkes, Lieut.
Townsend, N.
Tucker, V. (killed in action).
Turner, W. A.
Twine, G. J.
Ulrich, Gerard A.
Veitch, Neil A.
Wallman, H. P., Lieut.
Warde, Harvey S. (killed in action).
Waters, Professor D. B., Capt.
Watts, R. T. (killed in action).
Wentworth, D'Arcy.
Weigall, H. S., Colonel
Williams, O. B., Major, M.C.
Wilkins, Lawrence G., Lieut.
Woodward, O. H., Capt., M.C. and three bars.
White, J. M., Lieut., M.C.

AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY.

Balance Sheet, 31st December, 1919.

LIABILITIES.

Subscriptions paid in advance				£19	10	0
Sundry Creditors				70	0	0
J. W. Sutherland Prize unexpended ...				52	10	0
Accumulated Fund—						
Balance at 31st Dec., 1918	£1443	7	10			
Add Surplus transferred from Revenue A/c ...	135	9	9			
				1578	17	7
				£1720	17	7

ASSETS.

State Savings Bank at Credit	£224	4	7			
Commonwealth Savings Bank at Credit	104	15	1			
				£328	19	8
Commonwealth of Australia War Loan	1000	0	0			
Commonwealth of Australia War Savings Certificates (at face value)	125	0	0			
				1125	0	0
Outstanding Subscriptions				206	17	0
Sundry Debtors				16	10	0
Office Furniture, Melbourne and Broken Hill Branch				43	10	11
				£1720	17	7

Melbourne, 19th January, 1920.

Audited and found correct.

Oxlade & Mackie, Auditors.

Statement of Receipts and Expenditure for the Year ended 31st December, 1919.

RECEIPTS.

	£	s.	d.	£	s.	d.
Dec. 31st, 1918.						
To Commonwealth Savings Bank at Credit ...	£83	3	11			
State Savings Bank at Credit	300	0	0			
Dec. 31st, 1919.				£383	3	11
Members' Subs., 1917 ..	1	11	6			
" " 1918 ...	66	19	0			
" " 1919 ...	635	5	5			
" " 1920 ...	16	17	6			
" " 1921 ...		10	6			
				721	3	11
Advertisements ...	49	0	0			
Sales	6	5	0			
J. W. Sutherland Donation (Student's Prize)	52	10	0			
Entrance Fees	21	12	6			
Interest—Commonwealth Savings Bank ...	1	15	7			
Interest—State Savings Bank	24	4	7			
Interest—War Loan ...	60	10	0			
				215	17	8
				£1320	5	6

EXPENDITURE.

	£	s.	d.	£	s.	d.
By Printing & Stationery ...	£46	11	6			
Rent	50	0	0			
Salaries	250	0	0			
Postages, Telegrams, &c.	62	12	3			
Sundries	50	7	10			
A. T. Danks Prize ...	10	0	0			
Proceedings	371	17	5			
Commission	7	4	6			
Meeting Expenses ...	59	14	10			
Furniture	22	7	6			
Commonwealth of Australia War Saving Certificates (Face Value)	60	10	0			
				991	5	10
Commonwealth Savings Bank at Credit ...	104	15	1			
State Savings Bank at Credit	224	4	7			
				328	19	8
				£1320	5	6

REVENUE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1919.

1919.							
Dec. 31.	To Publications	£310	17	5			
	Stationery & Printing ...	36	11	6			
	Meeting Expenses ...	79	14	10			
	Postages, Telegrams, &c....	62	12	3			
	Salaries ...	250	0	0			
	Rent ...	50	0	0			
	Sundries ...	60	7	10			
	Commission	7	4	6			
					£857	8	4
	Balance transferred to Accumulated Fund ...				135	9	9
					£992	18	1

1919.							
Dec. 31.	By Subs., 1917 ...	£1	11	6			
	,, 1919 ...	816	8	11			
	Advertisements	60	10	0			
	Sales ...	6	5	0			
	Entrance Fees	21	12	6			
	Interest ...	86	10	2			
					992	18	1
					£992	18	1

Melbourne, 19*th January*, 1920. Audited and found correct. OXLADE & MACKIE, *Auditors.*

OF THE EXECUTIVE COMMITTEE.

(Summary.)

Feb. 27th, 1920—1 p.m.

The secretary's report was adopted and accounts to the amount of £121 passed for payment.

Mr. J. M. Bridge was elected to a casual vacancy on the Council.

Committees for 1920 were appointed as follow:—

Publication and Education—Messrs. H. W. Gepp, H. Herman, G. C. Klug, C. F. Courtney, Colin Fraser, G. H. Broome, W. E. Wainwright, and Professor Skeats.

Finance—Messrs. George Weir, A. S. Kenyon, H. Herman, and Colin Fraser.

Branches—Messrs. G. H. Broome, R. C. Sticht, G. C. Klug, George Weir, and the Chairman of each Branch.

Mine Managers' Certificates—G. H. Broome, H. Herman, and A. H. Merrin.

Estimates for 1920 were referred to the Finance Committee to report to the next meeting.

Nomination of Mr. Joseph Grigg as a member was deferred for fuller particulars. Nomination of Mr. Joseph Miller was approved.

The following were admitted to the Institute:—as Members.—Messrs. David Avery, Joseph Miller, W. J. M'Bride, and J. R. Pound; transfer from Associate Member to Member—Mr. O. B. Williams; as Associate Members—Garnet I. Adcock, Norman R. Junner, Herbert J. Robertson, and Milton A. Williamson.

Resignations of Messrs. H. W. Ford and T. J. Greenway were accepted.

The death of Mr. W. C. F. Rankin was reported, and a minute of sympathy recorded.

A letter was submitted from the Institute of Science and Industry stating that it would be pleased to arrange for the mining industry to be represented on any committees in which members of the Aust. Inst. M. and M. were particularly interested.

The action of the Australian Mines and Metals Association in dealing with a circular on values of ore reserves, issued by a member of the Adelaide Stock Exchange, and referred to the Association by the Institute, was approved.

Location of the First Ordinary Meeting 1920 was referred to the Branches Committee for report to the next meeting of the Executive Committee.

A recommendation was received from the Mount Morgan Branch that the Institute advocate the adoption of the metric system.

March 29th, 1920—1 p.m.

The Secretary's report was adopted, and accounts to the amount of £60 passed for payment.

Resolved that £250 worth of Commonwealth Bonds be purchased.

Nominations as follow were submitted and approved:—As Members—Messrs. Joseph Grigg and Alex. Robert Graham; as Associate Member—Mr. Harry Vernon Pethebridge; as Student—Mr. John Alexander Dunn.

Resignation of Mr. D'Arcy Wentworth was accepted with regret.

Deaths of Arthur E. Tandy (Lieut.), killed in action at the Front, and of Douglas G. Marks (Lieut.-Col.), drowned whilst attempting to rescue a bather in distress, were reported.

Report of Publication Committee was submitted and adopted.

The question of the best purpose to which Mr. J. W. Sutherland's donation of fifty guineas could be devoted was further considered, and it was reported that suggestions thereon had been invited from all members of Council.

A letter was submitted from Mr. G. H. Blakemore, accompanied by a cheque for £50, for the same purpose as Mr. Sutherland's donation. A hearty vote of thanks was accorded Mr. Blakemore on behalf of the Institute. It was resolved that a decision regarding the allocation of this fund be deferred pending receipt of further suggestions from members of Council.

Resolved that an address of welcome be presented to H.R.H. the Prince of Wales upon the occasion of his visit to Australia.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holidays.

MOVEMENTS OF MEMBERS.

A. F. S. ANDERSON has returned from Namtu, Northern Shan States, Burma, and is now at New Norfolk, Tasmania.

W. T. ANDERSON (Lieut.), who enlisted in December, 1914, and sailed with the Mining Corps, returned to Australia on 14th December, 1919. Whilst in Great Britain he had 10 months' experience in open-hearth steel furnace work with John Lysaght and Sons. He was also with the Stelton Iron and Steel Co., David Colville and Sons, and William Beardmore and Co.

H. WHEELER BROWN returned from active service on 24th November, 1919, and is now on the staff of the Broken Hill Proprietary Co. at Hummock Hill, S.A.

PERCY BURBRIDGE returned to Australia from active service in France in 1919, and is at present on the staff of the Mount Elliott Co., Selwyn, North Queensland. Prior to enlisting he was at the Mount Shamrock mine, Mount Shamrock, Queensland.

W. R. CAITHNESS is now located at 257 Clarence-street, Sydney, N.S.W.

A. G. CAMPBELL (Capt.) has been appointed to a position on the staff of the Burma Mines Ltd., Namtu, Northern Shan States, Upper Burma.

NOEL CARLESS returned from active service in France in December, 1919, and is at present at his home, Walney House, Waihi, N.Z.

WALTER COLLEY has accepted an appointment with the State Smelters at Chillagoe, Queensland.

BASIL G. DUNSTAN has been appointed manager of the Australian State Quarries, Willunga, S.A.

I. B. FABRIKANT is now in America, occupying the position of chemist at the Great Falls plant of the Anaconda Copper Mining Co.

John S. Foxall returned from active service with the A.I.F. on 28th August last. He was with the First Tunnelling Company in France and Belgium, and has resumed his former position as surveyor on the Sons of Gwalia mine, Gwalia, W.A.

F. H. Hooper has returned from active service with the A.I.F., and is now in his former position with the Broken Hill Block 14 Co., at Broken Hill.

Eric W. Hughes expects to return to Australia in June or July of this year. After serving with the A.I.F., he won one of the Soldier Scholarships presented by Mr. Otto Beit, and has been studying at the Royal School of Mines at South Kensington.

Arthur Jarman, formerly with the Waihi Grand Junction Co., Waihi, N.Z., is now engaged in construction work at Berkeley, Cal. His address is 1001 Spruce-street, Berkeley, Cal., U.S.A.

John F. Key has returned to Australia after serving with the A.I.F. He is at present on the staff of the British mine at Broken Hill.

Wm. J. Lakeland (Major), writing from Bagdad, Mesopotamia, on 29th February, states that he expects to be demobilized in a few days. His address will then be care Burma Finance and Mining Co., 10 Phayre-street, Rangoon, Burma.

Keith B. Lewis (Lieut.) returned from active service with the A.I.F. on 11th September, 1919. He enlisted in January, 1915, and sailed with the 22nd Battalion. He was invalided home in 1916, and after three months returned to the Front with the Second Tunnelling Company.

Reginald R. Marshall has been transferred from Adelaide to the Central mine at Broken Hill.

J. F. M'Padden has resumed his position as director of the Reefton School of Mines, N.Z., after a period of active service in France.

Karl Byron Moore (Lieut.) returned from active service last year, and is now on the staff of the Electrolytic Zinc Co. of Australia in Melbourne.

V. H. R. Murray has been appointed underground manager of the Golden Horseshoe Estates Co., Boulder, W.A.

H. V. Petherbridge (Lieut.), who was for some years on active service, is now on the staff of the Electrolytic Zinc Co. of Australia at Risdon, Tasmania.

H. C. Robson has resigned from the position of smelter superintendent at the Spassky Copper Mines Ltd., Siberia. His address now is "Silverdale," Penzance, Cornwall, England.

J. B. Shaw (Lieut.), M.C., enlisted in the A.I.F. in August, 1916, and was attached to the Third Australian Tunnelling Co. He returned to Australia on 15th December, 1919.

H. Frank Shepherd, late of Thames, N.Z., is now manager of the Hauraki Mines, Coromandel, N.Z.

R. T. Slee has been appointed manager of the Broken Hill Proprietary Co. at Broken Hill, N.S.W.

Augustus Taylor enlisted with the A.I.F. in 1915, and recently returned to Australia. He is at present on the staff of the Geological Survey Department, Sydney, N.S.W.

Rupert M. Vaughan, recently with the Briseis Tin and General Mining Co., Derby, Tasmania, has sailed for England. His address is Melton Bryon Rectory, Woburn, Beds., England.

D'Arcy Wentworth returned from active service in June, 1919, and is now in Sydney.

A. S. Winter, late of Nymagee, is now at the C.S.A. Mines Ltd., Cobar, N.S.W.

Oliver H. Woodward (Capt.), who recently returned after 3½ years' active service, has accepted a position on the general manager's staff of the Broken Hill Associated Smelters at Port Pirie. Prior to enlisting he was in the metallurgical department of the Mount Morgan G.M. Co.

OBITUARY.

Henry E. Hammel (Lieut.) has been reported killed in action in France on 22nd May, 1918. He was an associate member of the Institute. In 1913 he was on the staff of the Great Fitzroy Mines Ltd., Mt. Chalmers, Queensland, and later with the Mount Morgan Co.

DOUGLAS G. MARKS was drowned at Palm Beach, Sydney, on 25th January, 1920, in a gallant attempt to rescue a bather in distress. He served with distinction at the Front, and attained the rank of Lieut.-Colonel. He was a student-member of the Institute.

W. F. SMITH, student, late of the Charters Towers School of Mines, has been reported killed in action during 1918.

ARTHUR E. TANDY.—Word has come to hand that Arthur E. Tandy was killed in action in France on 2nd April, 1918. He was an associate member of the Institute, and his home was at "Glen Rowan," Warreemba-road, Abbotsford, N.S.W.

MEMBERSHIP.

Since the last issue of Proceedings the following have been admitted to the Institute:—

Members.

AVERY, DAVID, Collins House, Melbourne, Vic.
MILLER, JOSEPH, Story's Creek, Tas.
M'BRIDE, WM. JOHN, Broken Hill South Ltd., Broken Hill, N.S.W.
POUND, JAMES ROBERT, School of Mines, Ballarat, Vic.

Transfer from Associate Member to Member.

WILLIAMS, OWEN BERESFORD, Block 10 Mine, Broken Hill, N.S.W.

Associate Members.

ADCOCK, GARNET INGAMELLS, Rutherglen, Vic.
JUNNER, NORMAN ROSS, School of Mines, Ballarat, Vic.
ROBERTSON, HERBERT JAMES, Junction North Broken Hill Mine, Broken Hill, N.S.W.
WILLIAMSON, MILTON ARTHUR, Junction North Broken Hill Mine, Broken Hill, N.S.W.

Student.

DUNN, JOHN ALEXANDER, Bendigo Amalgamated Goldfields N.L., Bendigo, Vic.

Applications for admission to the Institute have been received from the following:—As Members—Messrs. **William Horace Campbell**, Associated Smelters, Port Pirie, S.A.; **Josiah Crabb**, Southern Cross, W.A.; **George Dey**, Associated Smelters, Port Pirie, S.A.; **Alexander Robert Graham**, State Coal Mine, Wonthaggi, Vic.; **Joseph Grigg**, Pahang Consolidated Mines, Sungei Lembing, F.M.S.; **Ernest Kingsbury Hall**, Junction North Mine, Broken Hill, N.S.W.; **Carl Sidney Horman**, Kalgoorlie, W.A.; **Arthur Francis Hosking**, Beaconsfield, Tas.; **Edric Noel Mulligan**, Sydney, N.S.W.; **Peter James Walsh**, Associated Smelters, Port Pirie, S.A., and **Douglas de C. Wilson**, Junction North Mine, Broken Hill, N.S.W. Transfer Associate Member to Member—Messrs. **John M. Bridge**, Zinc Corporation Ltd., Broken Hill, N.S.W.; **Alex. D. Mackay**, Melbourne, Vic., and **David N. Morison**, Newcastle, N.S.W. As Associate Members—Messrs. **Ralph V. Berriman**, Prospect, S.A.; **Hubert Henry Carroll**, Mount Lyell M. and R. Co., Gormanston, Tas.; **Francis Henry Hooper**, Block 14 Co., Broken Hill, N.S.W.; **Carl Josef Linz**, Broken Hill South Ltd., Broken Hill, N.S.W.; **Harry Vernon Pethebridge**, Electrolytic Zinc Co. of Australia, Hobart, Tas.; **Frederick Albert Rufus**, Block 10 Co., Broken Hill, N.S.W.; **Arthur Howard Swan**, Zinc Corporation Ltd., Broken Hill, N.S.W., and **Montague Lewis Warren**, Associated Smelters, Port Pirie, S.A.

FIRST ORDINARY MEETING, 1920.

Arrangements are being made for holding the First Ordinary Meeting, 1920, at Port Pirie and Wallaroo, S.A. The Broken Hill Associated Smelters and the Wallaroo and Moonta Mining and Smelting Co. have sent a cordial invitation to the Institute to visit and inspect their works. A most interesting and instructive visit is, therefore, assured. A programme will shortly be issued, but in the meantime members are advised to make arrangements to enable them to take part in the excursion. Concessions in travelling fares will be arranged and hotel accommodation secured on notification to the Secretary. The party will most probably leave Adelaide on Monday, 16th August.

PUBLICATIONS.

Papers included in this issue are :—

"Notes on the Work of an Australian Tunnelling Company in France," by O. H. Woodward.

"Some Controlling Factors in Flotation," by Ralph D. Nevett.

"Isometric Mine Plans." by H. Edward Clayton ; discussion by J. S. Foxall.

DONATIONS.

As announced in the Annual Report of the Council, Mr. J. W. Sutherland (Member of Council) generously placed in the hands of the Council the sum of fifty guineas to be used at the discretion of the Council for the purpose of encouraging students in mining and metallurgy by means of prizes or medals or to help forward any of the other objects of the Institute. The Publication and Education Committee has been deputed to give effect to Mr. Sutherland's wishes. Following Mr. Sutherland's example, Messrs. G. H. Blakemore and W. E. Wainwright (Members of Council) have each forwarded cheques for £50 for a similar purpose. The Council desires, on behalf of members, to express its thanks and appreciation for these generous donations.

EMPLOYMENT REGISTER.

The Employment Register, inaugurated in 1917, has been of considerable assistance in securing positions for members. Members desiring engagement are requested to forward to the Secretary, for filing, full particulars of their qualifications and experience, copies of references, and the class of engagement they desire.

ELECTION TO COUNCIL.

Mr. J. M. Bridge, hon. secretary of the Broken Hill branch, has recently been elected a member of Council.

INSTITUTE OF SCIENCE AND INDUSTRY.

The Institute of Science and Industry has notified the Aust. Inst. M. and M. that it will be pleased to arrange for the mining industry to be represented on any committees in which members of the Aust. Inst. M. and M. are particularly interested.

NEW CONSTITUTION.

The final draft of the new constitution will shortly be issued to members for ballot. Members are advised to make themselves conversant with the clauses therein. The final draft will differ in only a few minor points from the copy already in the hands of members.

ANNUAL SUBSCRIPTIONS.

All members, associate members and students under the present constitution will automatically be transferred to a similar grade under the new constitution when adopted, but only on payment of arrears of subscription, if any. The Council trusts, however, that no exclusions will be necessary on this account, but this rests entirely with members themselves.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY
FROM 31ST DECEMBER, 1919 TO 31ST MARCH, 1920.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
Institute of Science and Industry : Journal, Vol. I., Nos. 6-8 ; Vol. II., Nos. 1 and 2 Bulletin, Nos. 1, 3, 7, 8 and 15		Melbourne
Department of Mines, Victoria : Annual Report, 1918		Melbourne
Royal Society of Victoria : Proceedings, Vol. XXXII., Part 1		Melbourne
Department of Mines, New South Wales : Annual Report, 1918		Sydney
Royal Society of Tasmania : Transactions, Vol. XLIII. Papers and Proceedings, 1919		Hobart

Department of Mines, Tasmania :
- Geological Survey, Report, No. 8
- Mineral Resources, No. 6
- Bulletins, Nos. 30 and 31 - - - Hobart

New Zealand Journal of Science and Technology :
- Journal, Vol. III., No. 1 - - - Wellington

Institution of Mining and Metallurgy :
- Bulletins, Nos. 181-184 - - - London

Geological Society : Quarterly Journal, Nos. 296 and 297 London

Geologists' Association : Proceedings, Vol. XXX., Part 4 London

Institution of Mining Engineers :
- Transactions, Vol. LVIII., Part 1 - - London

Geological Survey of Great Britain :
- Summary of Progress, 1918 - - - London

Geological Institution of the University of Upsala :
- Bulletin, Vol. XVI., 1919 - - - Upsala

Sveriges Geologiska Undersokning :
- Publications, Nos. 14-16 - - - Stockholm

Geological Survey of India :
- Records, Vol. L., Parts 3 and 4 - - Calcutta

Mining and Geological Institute of India :
- Transactions, Vol. XIV., Part 1 - - Calcutta

Department of Mines, Canada :
- Summary Report of the Mines Branch, 1918
- Production of Coal and Coke in Canada during 1918
- Annual Report of the Mineral Production of Canada, 1918
- The Production of Copper, Gold, Lead, Nickel Silver, Zinc and other Metals - - Ottawa

Bureau of Mines, Ontario :
- 28th Annual Report, Vol. XXVIII., Part 1 - Toronto

American Institute of Mining and Metallurgical Engineers :
- Bulletins, Nos. 156-159 - - - New York

California State Mining Bureau :
- Bulletin, No. 86
- Summary of Operations, California Oil Fields, April to Oct., 1919 - - - Sacramento

Instituto Geologico de Mexico :
- Annales, Vol. V., Nos. 8 and 9 - - Mexico

Department of Mines, Mexico :
- Bulletin, Vol. VII., Nos. 5 and 6 - - Mexico

RECENT ARTICLES ON MINING MATTERS.

(31st December, 1919, to 31st March, 1920).

NOTE.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c., due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Transactions*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng., New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London.

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

GEOLOGICAL.

Ore Deposits of Utah. B. S. Butler. (6) Serial commenced Oct. 11, 1919.
The Tungsten Resources of the World. F. L. Hess. (6) Nov. 1, 1919.
The Petroleum Resources of the World. J. D. Northrop. (6) Dec. 27, 1919.

METALLURGICAL.

The Use of Napthylamin and Xylidin in Flotation. E. H. Robie. (6) Nov. 1, 1919.
Differential Flotation of Zinc-Lead Sulphides Improved by Metallizing the Blende. (6) Dec. 27, 1919.
Flotation at Pitcher, Okla. V. Lott. (6) Dec. 27, 1919.
Rapid Determination of Silver in Cyanide Solutions. J. E. Clennell. (6) Nov. 8 and 15, 1919.
Precipitate Smelting at Tonopah. G. J. Young. (6) Dec. 13 and 20, 1919.
Cottrell Electrical Precipitation Process in Japan. R. Hirota and K. Shiga. (6) Dec. 13 and 20, 1919.
New Modderfontein Gold Mining Co. Mill and Treatment Plant at Circular Shaft. E. M. Weston. (6) Jan. 20, 1920.
Smelting Zinc-Lead Ores. C. Hall. (8) Nov. 15, 1919.
Mill Tests v. Hand-Sampling. H. R. Sleeman. (8) Nov. 15, 1919.
The Discovery of Froth Flotation. James Hebbard. (8) Nov. 22, 1919.
Flotation in Stages. B. Stevens. (8) Nov. 22, 1919.
Selective Flotation by the Horwood Process. Wm. Motherwell. (8) Nov. 29, 1919.
The Concentration of Platinum in Placer Mining. K. C. Laylander. (8) Dec. 20, 1919.
Fine Grinding in Ball Mills. H. Hanson. (8) Jan. 3, 1920.
Chloridizing Processes. H. R. Layng. (8) Jan. 17, 1920.
Experimental Flotation of Low-Grade Quicksilver Ore. E. G. Stowell and W. H. Coghill. (8) Jan. 24, 1920.
Elements of Smelting-Plant Design. O. E. Jager. (8) Serial commenced Jan. 31, 1920.
De-Gassing Cyanide Solutions. P. Argall. (8) Feb. 14, 1920.
Some Ideas on Ball-Mill Practice. C. Lindley. (8) Feb. 14, 1920.
A Contribution to the Study of Flotation. H. L. Sulman. (25) Bull. No. 182.
Froth Flotation: Its Commercial Application and Its Influence on Modern Concentration and Smelting Practice. W. Broadridge. (25) Bull. No. 184.
Relationship of Physical and Chemical Properties of Copper. F. L. Antisell. (29) Bull. No. 157.
Forgeability of Iron–Nickel Alloys. T. D. Yersen. (29) Bull. No. 157.
Reverberatory Furnace for Treating Copper Slag at Anaconda. F. Laist and H. J. Maguire. (29) Bull. No. 157.
Amalgamation, with Special Reference to Steaming. (28) Nov., 1919.
The Permanganate Method for Copper. L. F. Clark. (43) Dec., 1919.
Interesting Facts Concerning Refractories in the Iron and Steel Industry. C. E. Nesbit and M. L. Bell. (43) Dec., 1919.
The Determination of Oxygen by the Copper–Ammonia–Ammonium Chloride Reagent. W. L. Badger. (43) Feb., 1920.
The Solubility of Zinc in Cyanide Solutions. H. A. White. (28) Dec., 1919.
An Unusual Process in the Treatment of Gold Ore. B. L. Gardiner. (28) Jan., 1920.
Flow-Sheet Conventions. A. G. Wolf. (6) Feb. 7, 1920.
Separating Metallics from Pacific Coast Sands. H. E. Wood. (6) Feb. 7, 1920.

MECHANICAL.

Jackhammer Type Drills in Witwatersrand Mines. E. M. Weston. (6) Feb. 7, 1920.
Mechanical Drafting in Mining and Metallurgy. H. E. West. (6) Feb. 7, 1920.
Rotary Rock Bits. A. G. Wolf. (6) Feb. 7, 1920.

MINING.

Standard Chutes for Metal Mines. C. A. Mitke. (6) Nov. 8 and 15, 1919.
Panel System of Stoping at the Herman Mine. S. H. Brockunier. (6) Dec. 6, 1919.
Standardized Crosscut Heads. H. Drullard. (6) Jan. 2, 1920.
Loading Machines for Underground Use. A. M. Gow. (6) Jan. 31, 1920.
Hanging-Wall Support on the Far East Rand. L. W. Macer. (28) Oct., 1919.

MISCELLANEOUS.

The Gold Situation. John Clausen. (6) Oct. 18, 1919.

Rand Ore Reserves. A. C. Key. (6) Nov. 1, 1919.

Notes on Final Report of the South African Miners' Phthisis Prevention Committee. E. M. Weston. (6) Dec. 27, 1919.

The Gold Mining Problem. (6) Nov. 8 and 15, 1919.

Ore Contracts. C. A. Grabill. (6) Serial commenced Nov. 22 and 29, 1919.

Mine Bookkeeping. C. B. Holmes. (6) Jan. 3, 1920.

The Banker and the Mining Problem. (6) Jan. 10, 1920.

The Economist and the Gold-Mining Problem. (6) Jan. 31, 1920.

Short Cuts in Mine Surveying. D. Waterman. (8) Nov. 22, 1919.

Minerals Separation *v.* Mining Industry. G. L. Nye. (8) Dec. 13, 1919.

A Calculator for Mine Valuation. R. B. Hoffmann. (8) Dec. 27, 1919.

Some Possible Causes of Discrepancies Between Mine and Buyers' Weights of Gold Bars. H. R. S. Wilkes. (28) Nov., 1919.

A History of Gold Discoveries in West Australia. C. M. Harris. (35) Nov., 1919.

Asbestos in the Beaconsfield District. A. M'Intosh Reid. (15) Geol. Surv. Report, No. 8.

The Iron Ore Deposits of Tasmania. W. H. Twelvetrees and A. M'Intosh Reid. (15) Mineral Resources, No. 6.

The Geologist as Engineer. (6) Feb. 7, 1920.

SUBSCRIPTIONS.

☞ Members are reminded that Subscriptions for 1920 are now due.

GUIDE TO CONTRIBUTORS OF PAPERS.

It is requested that writing be confined to *one* side of the paper ; that it be legible with particular care regarding foreign words; and that abbreviations, references, &c., be made in accordance with the subjoined rules and examples:—

Pounds, shillings, and pence, £ s. d. ; dollars and cents, $, c.
Grains, gr., pennyweights, dwt. ; ounces, oz. ; drachms, dr. ; pounds, lb.
Quarters, qr. ; hundredweights, cwt.; gallons, gal.
Grammes, grm. : kilogrammes, kg. ; millimetres, mm.: milligrammes, mg.
Centimetres, cm. : cubic centimetres, cc.; metres, m.
Inches, in. ; feet, ft. : yards, yd.; fathoms, fath.
Square inches, etc., sq. in. : cubic inches, etc., cub. in.
Diameter, diam.; revolutions, rev.; revolutions per minute, r.p.m.
Horse power, h.p.; indicated horse power, i.h.p.: brake horse power, b.h.p.
Candle power, c.p.
British thermal units, B.Th.U.
High pressure, H.P. : low pressure, L.P.
Ampere, amp. : kilowatts, kw.
Percentages, % ; degrees, ° ; specific gravity, sp. gr.
Company Limited, Co. Ltd.; and Company, & Co.
Temperatures to be given in Fahrenheit, thus : 10° Fahr.

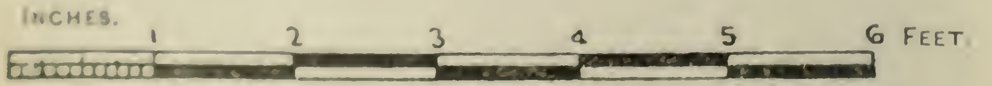
Figures not exceeding four, unless in column with others exceeding four, to be without comma, thus : 1907.

References to be placed in foot-notes, giving title in italics, thus : *Alfred James. *Cyanide Practice*, p. 94 ; † H. Brown. *Mines and Minerals*, vol. xiii., p. 130; ‡ *Trans. Aust. Inst. M.E.*, vol. x, pp. 98-189.

Quotations to be indicated by inverted commas, and when lengthy, to be set in smaller type, with inverted commas at beginning and end only. Foreign terms to be in italic.

Localisms to be in inverted commas with their ordinary technical definition in parenthesis.

Drawings (on tracing cloth if possible), photographs (unmounted glossy-surface bromides) or other glossy-surface prints, &c., both for exhibition and for publication, are most desirable with almost every communication, and should always be on separate paper from the MS. Blue-prints only to be forwarded when original plans or tracings are not procurable. When reference letters are used in drawings for purposes of description, they are best thus : *a b c*, etc. Lettering and figuring on drawings should be large to allow of reduction to page size whenever possible. All lines should be black and firm. Each drawing should be accompanied by scale thus :—



N.B.—When in doubt about any point, it would be advisable to communicate with the Secretary.

PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy.

NEW SERIES.

No. 38.

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

30th JUNE, 1920.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY, MELBOURNE.

Australasian Institute of Mining and Metallurgy.

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Broken Hill	C. H. J. Clayton, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. Patterson, Mount Morgan, Q.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 Queen Street, Melbourne, Victoria.

Institute Matters.

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MINUTES OF MEETINGS.

Of the Council.

June 9th, 1920—1 p.m. (Special Meeting).

Suggestions from members in regard to the second draft of the proposed new Constitution, issued early in the year, were considered. It was resolved that the clauses as amended be forwarded to all members of Council and that a special meeting of the Council be held on June 28th to receive and, if approved, to adopt the constitution as amended, also to give directions concerning the issue of the final draft and the date of the ballot thereon.

It was reported that the Broken Hill Strike was still proceeding, and that there was no present prospect of its early termination. The Council therefore resolved that the proposed visit to Port Pirie and to Wallaroo and Moonta be postponed.

JUNE 28TH, 1920—1 P.M. (Special Meeting).

Copy of the final draft of the proposed new Constitution was submitted and adopted.

The draft was then referred to the Solicitor for report.

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OF THE EXECUTIVE COMMITTEE.

(Summary.)

MARCH 27TH, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £58 passed for payment.

Applications for transfer from the grade of Associate Member from Messrs. A. D. Mackay and D. N. Morison were approved. Nomination of Mr. Edric N. Mulligan as a Member was also approved.

A paper by Mr. W. H. Mawdsley entitled "Sulphuric Acid: The Chamber Process under Tropical Conditions," was submitted and referred to the Publication Committee.

A donation of £50 by Mr. W. E. Wainwright towards the fund inaugurated by Messrs. Sutherland and Blakemore was reported and a vote of thanks accorded Mr. Wainwright. A decision regarding allocation of the fund was deferred pending receipt of further suggestions which were expected from Members of Council.

Report of progress in connection with the First Ordinary Meeting was submitted.

Other routine business was transacted.

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MAY 24TH, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £4 passed for payment.

Report of Annual Meeting of Broken Hill Branch containing list of officers elected was submitted and adopted.

Nominations as follow were approved:—

As Members—J. M. Bridge (transfer from Associate Member), E. K. Hall, Douglas de C. Wilson and A. F. Hosking. As

Associate Members—A. H. Swan, C. J. Linz, F. H. Hooper, F. A. Rufus, H. H. Carroll and R. V. Berriman. As Students—W. H. J. Cropp, H. L. Green and R. T. H. Dale.

Reports of Mining and Metallurgical Scholarships and Bursaries granted were submitted.

A paper entitled "The Geology and Ore Deposits of the Walhalla-Woods Point Auriferous Belt" by Norman Junner, D.Sc., was submitted and referred to the Publication Committee.

Suggestions in regard to the final draft of the proposed New Constitution were considered and further consideration deferred until 9th June.

Other routine business was transacted.

June 28th, 1920—1 p.m.

The Secretary's report was presented and accounts to the amount of £24 passed for payment.

Nominations as follow were approved :—

As Members—W. H. Campbell, Josiah Crabb, George Dey, Victor A. Haigh (transfer), C. S. Honman, Wm. Parsonage, G. Walls and P. J. Walsh. As Associate Members—R. G. Casey, W. R. Broad, G. E. Gabriel and R. K. Garnett. As Students—R. A. D. Meikle and Leo P. J. Gibbons.

Resignation of E. A. de Lautour was accepted.

Reports *re* Bursaries and Scholarships awarded by the Mining and Metallurgical Bursaries Committee were submitted and received.

Suggestions from the Broken Hill Branch in regard to the Institute Employment Register were submitted and copies distributed. Consideration was deferred in order that Members might make suggestions thereon after perusal.

Paper by Mr. L. V. Waterhouse entitled "Flotation Practice at Mount Lyell," was submitted and referred to the Publication Committee.

Mr. W. G. Langford was appointed Local Correspondent for Papua.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holidays.

MEMBERSHIP.

Since the last issue of Proceedings the following have been admitted to the Institute :—

Members.

Names and Addresses.

Hall, Ernest Kingsbury, Junction North Mine, Broken Hill, N.S.W.
Hosking, Arthur Francis, Beaconsfield, Tas.
Mulligan, Edric Noel, University Club, Sydney, N.S.W.
Wilson, Douglas de Courcy, North Mine, Broken Hill, N.S.W.

Transfer from Associate Member to Member.

Bridge, John Maurice, 1 Kooyong Road, Armadale.
Mackay, Alexander Dudley, 4 Fawkner Street, South Yarra.
Morison, David N., Newcastle, N.S.W.

Associate Members.

Carroll, Hubert Henry, Gormanston, Tas.
Hooper, Francis Henry, Block 14 Mine, Broken Hill, N.S.W.
Linz, Carl Josef, Broken Hill South Ltd., Broken Hill, N.SW.
Rufus, Frederick Albert, Block 10 Mine, Broken Hill, N.S.W.
Swan, Arthur Howard, Zinc Corporation Ltd., Broken Hill, N.S.W.
Berriman, Ralph Vaughan, 18 Daphne Street, Broken Hill, N.S.W.

Students.

Cropp, Walter Henry James, 65 Filleul Street, Dunedin, N.Z.
Dale, Roger Thomas Hilton, 47 Harrington Street, Port Chalmers, N.Z.
Gibbons, Leo. P. J., West Australian School of Mines, Kalgoorlie, W.A.
Green, Harold Litchfield, 141 Leith Street, Dunedin, N.Z.
Hopkins, Johns, Broken Hill Associated Smelters, Port Pirie, S.A.
Meikle, Robert Alexander Redvers, Dee Street, Mount Morgan, Q.

Applications for admission to the Institute have been received from the following:—As Members—Lionel Venn Brown, King Island; William Parsonage, Runanga, Greymouth, N.Z., and Goiders Walls, Devonport West, Tas. Transfer, Associate Member to Member—Messrs. Victor A. Haigh, Block 10 Mine, Broken Hill, N.S.W. As Associate Members—William T. Anderson, "Clifton," Ben Boyd Road, Neutral Bay, Sydney, N.S.W.; Richard G. Casey, 125 William Street, Melbourne, Vic.; Wilfred R. Broad, British B.H.P Co., Broken Hill, N.S.W.; G. Escott Gabriel, 327 Bromide Street, Broken Hill, N.S.W.; Robert K. Garnett, 554 Chapple Street, Broken Hill, N.S.W.; Harold F. Pearson, 388 Oxide Street, Broken Hill, N.S.W. These names are now submitted to members for confidential report.

FIRST ORDINARY MEETING, 1920.

As announced by Circular No. 2 the proposed visit to Port Pirie and Wallaroo and Moonta has been postponed on account of the continuance of the strike at Broken Hill. Unless the strike terminates at an early date it is probable that the proposed visit will be abandoned altogether this year.

PUBLICATIONS.

Papers included in this issue are:—

Flotation Practice at Mount Lyell. By L. V. Waterhouse, B.E. (Syd.), Member.

The Recovery of Zinc from Lead Blast-Furnace Slags. By Guy Courtney.

Sulphuric Acid: The Chamber Process under Tropical Conditions. By W. H. Mawdsley.

Treatment of Hard Water for Furnace Jackets. By A. S. Armstrong.

NEW CONSTITUTION.

The Memorandum and Articles of Association, under which the Institute will be incorporated, are being referred to the solicitor prior to their issue to members for ballot. As a further reference to members for suggestions is not now necessary the ballot will take place as soon as possible.

MINING AND METALLURGICAL BURSARIES.

The Mining and Metallurgical Bursaries Committee reports that the following Scholarships and Bursaries have been awarded for 1920:—

University.	Nature of Award.	Recipient.
Melbourne	Scholarship in Mining	R. B. Lewis
	Scholarship in Mining	H. R. Stafford
	Bursary in Metallurgy	T. W. Tobe
	Bursary in Metallurgy	Wm. E. Cerutty
	Bursary in Mining	G. C. Lindesay Clark
	Bursary in Mining	G. Keith Allen
Sydney	Scholarship in Metallurgy	E. G. Boyd
	Bursary in Metallurgy	Wm. M'Gregor
	Bursary in Mining	F. M. Jefferson
Adelaide	Scholarship in Mining	C. S. Kneebone
	Bursary in Mining	W. R. G. Colman

The Scholarship awarded to H. R. Stafford has been provided by the Cock's Pioneer Gold and Tin Mines, N.L., on its mining property at Eldorado, Vic.; those for E. G. Boyd and C. S. Kneebone are provided by the Mount Lyell Mining and Railway Co. Ltd. at its mine in Tasmania.

REPORTS OF BRANCHES.

BROKEN HILL BRANCH.

The Annual Meeting of the Broken Hill Branch was held on 3rd May, Mr. Andrew Fairweather in the chair.

The financial statement for 1919 was read and adopted, and the following officers elected for the 1920 session :—

Chairman—Mr. Andrew Fairweather.
Vice-Chairman—Messrs. C. C. Freeman and R. T. Slee.
Hon. Secretary—Mr. C. H. J. Clayton.
Hon. Treasurer—Mr. P. H. Warren.
Hon. Auditor—Mr. G. McI. Hunter.
Hon. Librarian—Mr. Victor A. Haig.
Committee—Messrs. A. S. Clark, J. Ewart, R. D. Nevett, W. D. Whiteman, H. Lavers, H. E. Garde, N. J. Roberts, F. N. Thomas, W. B. Chomley, O. B. Williams and E. M. Holder.

Mr. Molesworth, resident lecturer of the Workers' Education Association, explained the objects and scope of the Association, and suggested affiliation with the Branch. No action was taken.

An ordinary meeting of the Broken Hill Branch was held on 7th June, when, as requested by the Council, suggestions were formulated in regard to the extension of the Employment Register.

A paper entitled "The Contract Wage System for Mines," by A. K. Knickerbocker, published in Bulletin No. 153 of the American Institute of Mining and Metallurgical Engineers, was read and discussed.

MOVEMENTS OF MEMBERS.

Bernard V. Barton has severed his connection with the Seoul Mining Co., Holkol, Korea, and is at present in Melbourne.

W. B. Blyth, of Rhodesia, visited Australia recently, and was in Hobart in May last.

John M. Bridge, who was for seven years in charge of mining operations for the Zinc Corporation Ltd., Broken Hill, has been appointed engineer in charge of coal-winning operations at Morwell, Victoria.

C. H. J. Clayton is now underground manager of the Zinc Corporation's Mine at Broken Hill, N.S.W.

A. Lacey Court has returned from California, and is now on the staff of the Central Mine, Broken Hill, N.S.W.

Alex. J. Dubois (Capt.), who served throughout the war, has returned to civil life and is at present interested in tin mining in Cornwall.

F. F. Espie, late of Burma, is now residing at Semaphore, S.A.

F. W. R. Godden, Local Correspondent for W.A., and for some years with the Ivanhoe Gold Corporation, Boulder, W.A., is now manager of the Hampton Properties Leases. His address is Hampton Properties Ltd., Block 50, Hampton Plains, W.A.

Norman Junner has had the degree of D.Sc. conferred upon him by the Melbourne University. He sailed for England on May 28th, 1920. His London Address is c/o Gold Coast Geological Survey, Colonial Office, Downing Street, Westminster, London.

C. H. Lawn, of Stratford, Taranaki, N.Z., has been promoted to the position of Office Engineer to the Taranaki District Office of the N.Z. Public Works Department. Mr. Lawn is honorary secretary to the Taranaki Branch of the New Zealand Society of Civil Engineers.

H. H. Schlapp left Melbourne in June on a visit to America. He will be abroad for about six months.

J. B. Shaw arrived in London early in May, and is engaged in metallurgical work on behalf of the Electrolytic Zinc Company of Australia.

Professor E. W. Skeats, Member of Council, sailed for London by R.M.S. Orsova on 2nd June, and will be absent for nine months.

Gerard A. C. Ulrich enlisted in the British section of the N.Z. forces in September, 1914, and, later, joining the main forces in Egypt, took part with the field engineers in the Gallipoli campaign. He was invalided to England and, after 2½ years' treatment, was discharged in 1918. At present Mr. Ulrich is assistant manager of the Ashantee Goldfields Corporation, Obuas, Gold Coast Colony, West Africa.

Laurence G. Wilkins (Lieut.), who enlisted with the 2nd Australian Tunnelling Co. in August, 1915, returned to Australia in July, 1919.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY
FROM 31ST MARCH, 1920 TO 30TH JUNE, 1920.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
Department of Mines, New South Wales : Mineral Resources, No. 29		Sydney
Department of Mines, Queensland : Geological Survey, Bulletins, Nos. 265 and 267		Brisbane
Department of Mines, South Australia : Mining Review for Half-Year ended Dec. 31, 1919		Adelaide
The University of Adelaide : Calendar, 1920		Adelaide
Royal Society of South Australia : Transactions, Vol. XLIII.		Adelaide

New Zealand Geological Survey :
  Bulletin, No. 22 - - - - Wellington
New Zealand Journal of Science and Technology :
  Chrome-iron Ores, Mica and Tungsten Ore in N.Z., by P. G. Morgan
  Graphite in N.Z., by P. G. Morgan
  Mokau Sub-division ; The Taranaki Goldfield, by J. Henderson
  Coal Prospects of Waiwera, Auckland, by J. A. Bartrum
  Permo-Carboniferous (Matai) Rocks of the Eastern part of the South Island of N.Z., by P. G. Morgan
  The Splitting of the Mangantine-Matipo Coal Seam, Buller Mountain Coalfield, by P. G. Morgan
  The Application of a Change of Volume Factor to the Correlation of Coal Seams and Coal Bearing Strata, by P. G. Morgan
  Talc, Manganese Ore, Clay, Fullers Earth and Oil Shale in N.Z., by P. G. Morgan - - Wellington
Institution of Mining and Metallurgy :
  Bulletins, Nos. 185-188 - - - London
Institution of Mining Engineers :
  Transactions, Vol. LVIII., Parts 3 and 4 : Vol. LIX., Parts 1 and 2 - - - London
Geologists' Association :
  Proceedings, Vol. XXXI., Parts 1 and 2 - London
Institution of Mechanical Engineers :
  Proceedings, Oct.-Dec., 1919 - - London
Institute of Chemistry of Great Britain and Ireland :
  Proceedings, 1919, Part 4 - - - London
Iron and Steel Institute :
  Journal, XCIX., No. II., 1919 - - London
Royal Dublin Society :
  Economic Proceedings, Vol. II., No. 14
  Scientific Proceedings, Vol. XV., Nos. 35-48 - Dublin
Société des Ingenieurs Civils de France :
  Mémoires—8th Series, Nos. 7-12 - - Paris
Annales des Mines :
  Vol. VIII., Part 4, Vol. IX., Parts 2-4 - Paris
Societa Geologica Italiano :
  Bulletin, Vol. XXXVIII. (1919), Parts 1-3 - Rome

Geological Survey of India :	
Records, Vol. LI., Part 1 - - -	Calcutta
Department of Mines and Geology, Mysore :	
Records, Vol. XVII., Part II.	
Bulletin, No. 9 - - - -	Bangalore
Mining and Geological Institute of India :	
Transactions, Vol. XIV., Part 2 - -	Calcutta
Department of Mines, Canada :	
Production of Iron and Steel in Canada during 1918	Toronto
Nova Scotian Institute of Science :	
Proceedings and Transactions, Vol. XIV., Part 3 and 4	Halifax
Canadian Mining Institute :	
Transactions, 1919, Vol. XXII. - -	Montreal
American Institute of Mining and Metallurgical Engineers :	
Bulletins, Nos. 160-162 - - -	New York
Department of Mines, Mexico :	
Bulletin, Vol VIII., Nos. 3 and 4 - -	Mexico
Secretaria de Industria Y Comercio :	
Bulletin, Vol. VIII., Nos. 5 and 6 - -	Mexico

RECENT ARTICLES ON MINING MATTERS.

(31st March, 1920, to 30th June, 1920).

NOTE.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c., due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Transactions*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng. New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London.

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

GEOLOGICAL.

Identification of Potash Deposits. W. H. Ross and A. R. Merz. (6) March 6, 1920.
Ore Deposits of Mexico. S. J. Lewis. (6) Serial commenced March 20, 1920.
Tin and Tungsten Deposits: the Economic Significance of Their Relative Temperatures o Formation. W. R. Jones. (25) Bull. No. 186. Discussion: No. 187.
Earth and Rock Pressures. H. G. Moulton. (29) Bull. No. 159.
Rapid Formation of Lead Ore. H. A. Wheeler. (29) Bull. No. 158.
The Formation of Coal. J. D. Kendall. (27) Vol. XXII.
The Distribution of Ore in Depth. J. D. Kendall. (35) May, 1920.

MECHANICAL.

Piston Drills for Use with Hollow Steel. E. M. Weston. (6) Feb. 21, 1920.
Loading Chute for Heavy Material. J. S. Watts. (6) Feb. 28, 1920.
Aerial Tramways. D. Lay. (6) Feb. 28, 1920.
Underground Hoisting Arrangement. (6) March 20, 1920.
Oil Well Pumping Methods and Equipment. S. S. Langley. (6) March 27, 1920.
Progress in Powdered Coal for Blast Furnaces. W. L. Wotherspoon. (6) April 3, 1920.
A Safety Crosshead for Bucket Shafts. J. E. Harding. (6) April 3, 1920.
Electrical Equipment of the Mill. B. B. Beckett. (6) April 10, 1920.
Water Economy in Mills. D. Lay. (6) April 10, 1920.
Coal Pulverizing Plant at Nevada Consolidated Copper Smelter. R. E. H. Pomeroy. (29) Bull. No. 158.
Unwatering the Rio Tinto Mine by Air-Lift. S. F. Shaw. (29) Bull. No. 158.
Operation of the Oil-Fired Assay Furnace. F. Borzynski. (8) May 15, 1920.
Practical Notes on the Design and Treatment of Steel Castings. G. F. Preston. (36)
Application of Pulverized Coal in Blast Furnaces. E. P. Mathewson and W. L. Wotherspoon. (27) Vol. XXII.
Internal Corrosion of Wire Cables and a Method Suggested for its Detection. W. F. Robertson. (27) Vol. XXII.
A Scheme for Oiling Mine Cables in Place. W. F. Robertson. (27) Vol. XXII.
Rational Use of Coal for Power and Heat. J. Blizard. (27) Vol. XXII.

METALLURGICAL.

Car-Loading Grating. W. S. Evans. (8) April 10, 1920.
Critical Ranges of Some Commercial Nickel Steel. H. Scott. (29) Bull. No. 158.
Macrostructure of Iron and Mild Steel at High Temperatures. H. S. Rawdon and H. Scott. (29) Bull. No. 158.
A Peculiar Type of Intercrystalline Brittleness of Copper. H. S. Rawdon and S. C. Langdon. (29) Bull. No. 158.
Physical Changes in Iron and Steel Below the Thermal Critical Range. Z. Jeffries. (29) Bull. No. 158.
The Problem of Reducing Lead Sulphate. F. N. Flynn. (6) Feb. 21, 1920.
Accurate and Quick Determination of Copper in Slag. A. M. Smoot. (6) March 20, 1920.
Selective Flotation by the Bradford Process. (6) March 20, 1920.
The Present Status of the Stamp Mill. A. J. Clark. (6) April 10, 1920.
Cement Bottoms for Pneumatic Flotation Cells. (6) April 10, 1920.
Factors Affecting Zinc Consumption in Cyanide Practice. (6) April 10, 1920.
Economics of Ore Concentration. R. T. Hancock. (6) April 10, 1920.
Flotation Practice of the [illegible] Lease. L. F. Barber. (6) April 10, 1920.
Examination of Mill Returns. D. Lay. (6) April 10, 1920.
Thickeners and Dewatering Appliances. H. Hanson. (6) April 10, 1920.
Curves to Show What a Ball-Mill Should Do. T. E. Fisher. (6) April 10, 1920.
Tube-Mill Calculations. G. O. Dechler. (6) April 10, 1920.
An Improved Zinc Feeder. A. J. Clark. (6) April 10, 1920.
Sulphidizing Roasting of Slime Mill Tailings. W. L. Maxson. (6) April 10, 1920.
Gathering Tungsten Ore. J. [illegible]. (6) April 10, 1920.
A New Mechanical Sample Mixer. (6) April 10, 1920.
Dry Crushing and Direct Cyanidation. (6) April 10, 1920.

Electrolytic Zinc Plant of the Judge Mining and Smelting Co. at Park City, Utah. L. S. Austin (8) March 20, 1920.

A Modification of Horwood's Process for the Treatment of Copper-Zinc Ores. H. L. Hazen (8) March 27, 1920.

Discussion on Flotation at the Idaho School of Mines. (8) March 27, 1920.

Mine and Flotation Plant of the American Graphite Company, near Ticonderoga, New York G. E. Gatlin. (8) April 17, 1920.

Formulas for Determining the Tonnage of Products from Metallurgical Operations. A. H. Heller. (8) April 17, 1920.

Can Amalgamation be Dispensed With? E. M. Weston. (28) Feb., 1920.

Means Adopted on the New Goch Gold Mine for Reducing the Consumption of Mercury. H. J. Lee. (28) Feb., 1920.

Froth Flotation: its Commercial Application and its Influence on Modern Concentration and Smelting Practice: Discussion. W. Broadbridge. (25) Bull. No. 185.

The Use of Haloid Cyanides for the Purpose of Gold Extraction. T. B. Stevens and C. E. Blackett. (25) Bull. No. 185. Discussion: No. 186.

The Metallurgy of Complex Low-Grade Ores. C. S. Vadner. (8) April 10, 1920.

The Bunker Hill Enterprise. T. A. Rickard. (8) Serial commenced Jan. 3, 1920.

Chloride Roasting and Leaching at the Plant of the Tintic Milling Company. T. P. Holt. (8) April 28, 1920.

Low-Temperature Carbonization of Coal. S. W. Parr and T. E. Layng. (29) Bull. No. 158.

Use of Microscope in Malleable Iron Industry. E. Touceda. (29) Bull. No. 158.

Intercrystalline Brittleness of Lead. H. S. Rawdon. (29) Bull. No. 158.

Graphitization of White Cast-Iron. R. S. Archer. (29) Bull. No. 158.

Blast Furnace Flue Dust. R. W. H. Atcherson. (29) Bull. No. 158.

Volatilization in Assaying. F. P. Dewey. (29) Bull. No. 158.

The Analysis of Aluminium. J. E. Clennell. (35) Serial commenced Feb., 1920.

The Hemerdon Wolfram-Tin Mine. E. Terrell. (35) Feb., 1920.

Reverberatory Copper Smelting in Arizona. C. F. Mason. (6) May 8, 1920.

Determining Copper in Slag. F. E. Lathe. (6) May 1, 1920.

The Effect of Various Elements on Electrical Resistivity of Iron. A. L. Norbury. (36)

The Structure of Some Chromium Steels. J. H. G. Monypenny. (36)

Note on the Structural Constitution, Hardening, and Tempering of High-Speed Steel Containing Chromium and Tungsten. K. Honda and T. Murakami. (36)

Chromium Steels—Part II.: Effect of Heat Treatment on Electrical Resistivity. C. A. Edwards and A. L. Norbury. (36)

The Properties of Iron-Chromite and Carbon Steels—Part I.: Thermal Analysis. C. A. Edwards and H. Sutton. (36)

The Effect of Initial Temperature upon the Physical Properties of Steel. J. H. Andrew, C. P. Metler and A. Wragg. (36)

The Reduction of Silicon from the Slag in the Acid Open-Hearth Process. B. Yaneski and G. A. Wood. (36)

The Chemical and Thermal Conditions in Blast-Furnace Practice. H. E. Wright. (36)

Notes on Slag Conditions in Open-Hearth Steel-Making Practice. J. F. Wilson. (36)

The Distribution of Phosphorus in Steel Between the Points AC1 and AC3. J. H. Whiteley. (36)

The Valuation of Ores and Iron-Making Material. C. H. Ridsdale. (36)

Iron Portland Cement with a Classification of Cements made from Blast-Furnace Slag. E. H. Lewis. (36)

Some Defects in Electro-Deposited Iron. W. E. Hughes. (36)

The Utilization of Titaniferous Iron Ore in New Zealand. J. A. Heskett. (36)

British Blast-Furnace Practice. F. Clements. (36)

Notes on Routine Assaying at the Globe and Phoenix Mine, Southern Rhodesia. H. R. Edmands (28) April, 1920.

The Remodelled Arizona Hercules Concentrator. J. T. Shimmin. (6) May 15, 1920.

Some Equipment for a Copper Smelter. (27) Vol. XXII.

Roasting and Lead-Smelting Practice at the Port Pirie (S.A.) Plant of the Broken Hill Associated Smelters Ltd. Gilbert Rigg. (25) Bull. No. 188.

Recent Improvements in the Concentration of Molybdenite. H. H. Claudet. (27) Vol. XXII.

Nodulizing Copper Concentrate. O. Lachmund. (27) Vol. XXII.

The Commercial Feasibility of the Electric Smelting of Iron Ores in British Columbia. A. Stansfield. (27) Vol. XXII.

Concentration of Chromite. L. K. Fletcher. (27) Vol. XXII.

Graphite in Quebec and Alabama: a Comparison. H. P. H. Brumell. (27) Vol. XXII.

MINING.

Recovery of Caved Chutes. D. Lay. (6) March 6, 1920.
A Timber and Concrete Bulkhead. F. Hutchinson. (6) March 6, 1920.
Failure of Mine Timbers. G. J. Young. (6) March 6, 1920.
Shaft-Sinking Methods in the Butte District. H. Drullard. (6) March 20, 1920.
Notes on Shrinkage Stoping. D. Lay. (6) April 10, 1920.
Mining in Narrow Stopes. E. A. Colburn. (8) May 15, 1920.
Largest Capacity Gold-Mining Dredge in the World. H. G. Peake. (6) May 15, 1920.
Tunnelling in the Sand Dunes of the Belgian Coast. H. Tatham. (25) Bull. No. 188.
Mining Methods at Mond Nickel Mines. O. Hall. (27) Vol. XXII.
Use of Explosives in Mines. H. Y. Russel. (27) Vol. XXII.
Regrading Stopes, No. 4 Mine, Cumberland, B.C. C. Graham. (27) Vol. XXII.
Tunnelling at the Front. R. W. Coulthard. (27) Vol. XXII.
Mining in Chalk on the Western Front. I. B. Reynolds. (27) Vol. XXII.
Tunnelling Reminiscences. A. W. Davis. (27) Vol. XXII.

MISCELLANEOUS.

Canadian Mining Engineer: His Status. J. M'Evoy. (6) March 13, 1920.
The Unionization of Engineers. (6) March 20, 1920.
Mining Engineers, Real and Bogus. (6) April 10, 1920.
Fire Protection of Surface Plants. (6) April 10, 1920.
The Combination Method of Mine-Sampling. M. Webber. (8) Feb. 28, 1920.
The Premium on Gold. (8) March 13, 1920.
Neutralizing Mine Water on the Rand. F. Wartenweiler and E. H. Croghan. (8) March 13, 1920.
Registration of Engineers. F. Montijo. (8) March 20, 1920.
Physical Examination of Hoisting Engineers. C. A. Allen and Dr. A. L. Murray. (8) March 20, 1920.
Mine Sampling. W. H. Wagner. (8) March 27, 1920.
Prospecting for Gold and Other Ores in Western Australia. C. M. Harris. (Discussion.) (25) Bull. No. 185.
By-Product Coke Ovens of the Granby Consolidated. W. A. Williams. (8) April 24, 1920.
The Friction of Ventilating Currents. W. S. Weeks. (8) April 24, 1920.
Examination of Ores and Metals in Polarized Light. F. E. Wright. (29) Bull. No. 158.
The Mining Congress Gold Plan. (6) April 24, 1920.
The Metric System. (6) April 17, 1920.
Systematic Prospecting. W. H. Grant. (6) April 17, 1920.
Registration of Engineers. (8) May 8, 1920.
The Contract System in Mines. (8) May 8, 1920.
Tin: Its Political and Commercial Control. James M. Hill. (6) May 1, 1920.
The Rand Mining Industry. A. C. Key. (6) May 1, 1920.
Mercurial Poisoning. Dr. A. J. Orenstein. (28) April, 1920.
The Identification of Quartz Particles in Konimeter Samples. Dr. A. W. Rogers. (28) April, 1920.
Liquid Fuels: Their Uses, Production, Consumption, and Sources in Canada. B. F. Haanel. (27) Vol. XXII.
Some Notes on the Sampling of Coal-Mine Air. D. Michell. (27) Vol. XXII.
Industrial Co-operation. W. R. Ingalls. (27) Vol. XXII.
The Hampton Plains Discoveries, Western Australia. C. M. Harris. (35) May, 1920.

PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy.

NEW SERIES.

No. 39.

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

30th SEPTEMBER, 1920.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY. MELBOURNE.

Australasian Institute of Mining and Metallurgy.

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The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 QUEEN STREET, MELBOURNE, VICTORIA.

Institute Matters.

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MINUTES OF MEETINGS.

OF THE EXECUTIVE COMMITTEE.

(Summary.)

JULY 28TH, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £137 passed for payment.

Nominations as follow were submitted and approved:—As Member—Mr. Lionel Venn Brown. As Associate Members—Messrs. H. F. Pearson and W. T. Anderson. As Student—Mr. John Hopkins.

The following were admitted to the Institute:—As Members—Messrs. A. F. Hosking, Douglas de C. Wilson and Ernest K. Hall. As Associate Members—Messrs. R. V. Berriman (formerly Student), H. H. Carroll (formerly Student), F. H. Hooper (formerly Student), Carl J. Linz, F. A. Rufus and A. H. Swan.

Transfer from Associate Member to Member of the following were approved:—Messrs. J. M. Bridge, A. D. Mackay and D. N. Morison.

The following papers were submitted and referred to the Publication Committee :—"Treatment of Hard Water for Furnace Jackets," by A. S. Armstrong ; "The Scope of the Engineers in the Great War," by O. B. Williams.

Suggestions in connection with the extension of the Employment Register were considered and revised.

The Solicitor's recommendations in regard to the new Constitution were submitted and referred to a Special Meeting.

Resolved that as invited the Institute act as the Australian representative for the Royal College of Science and Technology in connection with the Royal School of Mines Frecheville Research Fellowships and that particulars respecting such Fellowships be forwarded to members and Lecturers at Universities and Schools of Mines.

AUGUST 30TH, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £62 passed for payment.

Resolved that the sum of £200 be invested in the Second Peace Loan.

Nominations as follow were approved :—George Alan More as Member and Frederick Valentine Ramsden as Associate Member.

A Sub-committee consisting of Messrs. G. C. Klug, W. E. Wainwright, J. M. Bridge, Colin Fraser and George Weir was appointed to deal with the following subjects :—(1) Architects Registration Bill, (2) Registration of Mining Engineers, (3) Company Flotation (Signatures to Prospectuses). The Committee was authorised to arrange a conference with other bodies in regard to No. 3 if necessary.

Resolved that Mr. Lawson, Premier of Victoria, be requested to submit the following suggestion to the next conference of Premiers :—

> "That an interstate conference of Chief Inspectors of Mines be held with a view to the drafting of a Bill to provide for uniform standards of examination for mining managers' certificates and for reciprocity between the States."

Report of applications received for the Royal School of Mines Frecheville Research Fellowships was submitted and directions given regarding transmission to London.

Consideration was given to a suggestion that some arrangement might be made for the simultaneous publication of papers, contributed to the Institute in publications of sister associations and vice versa. The matter was referred to the Publication Committee.

SEPTEMBER 30TH, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £18 passed for payment.

Nomination of Mr. Wm. H. C. Chapple as a Member was approved, and that of Mr. James Conway deferred for fuller particulars.

Resolved that an Ordinary Meeting be held on 17th December to examine ballots for alteration of Rules and for any other business the Council may bring forward.

Resolved that a Special Meeting of the Executive Committee be held on 6th October to receive and deal with communications from Members of Council in connection with the proposed new Constitution, final drafts of which were issued on 3rd September.

The appointment of delegates to the Council of the Australasian Association for the Advancement of Science, Hobart Meeting, was deferred until the Special Meeting of the Executive Committee on 6th October.

Resolved that the list of Members of the Institute be revised, printed and distributed.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holidays.

MEMBERSHIP.

Applications for admission to the Institute have been received from the following:—As Members—William Henry Charles Chapple, Cobar Gold Mines, Cobar, N.S.W.; Jas. Conway, Bowen, Qld.; and George Alan More, Singapore. As Associate Members—John Alexander Dunn, Bendigo Amalgamated Goldfields, Bendigo, Vic.; and Frederick Valentine Ramsden, 15 Alexander Street, Balaclava, Vic. These names are now submitted to members for confidential report.

PUBLICATIONS.

The following Paper is included in this issue:—

"The Geology and Ore-Deposits of the Walhalla-Wood's Point Auriferous Belt," by N. R. Junner, D.Sc.

Discussion thereon is invited.

ANNUAL MEETING, 1921.

The annual meeting of the Institute, 1921, will be held at 48 Queen Street, Melbourne, on Monday, 31st January, 1921, at 1 p.m. The business of the meeting will include the presentation of the annual report and balance sheet for 1920 and the election of officers to fill the annual vacancies. Should the new Constitution be adopted at the ordinary meeting convened for 17th December, 1920, the annual meeting will not be held until March, 1921 (see articles 37 and 85).

ORDINARY MEETING.

As previously notified an ordinary meeting of the Institute will be held at 48 Queen Street, Melbourne, on Friday, December 17th, 1920, at 1 p.m. The business of this meeting will include (1) Examination of ballots for adoption of the new Constitution, (2) Such other business as the Council may bring forward.

NEW CONSTITUTION.

The Council recommends the adoption of the new Constitution, the ballot upon which will be decided on 17th December. Should the ballot be in the affirmative the new rules become operative forthwith and incorporation will immediately be proceeded with. The process of incorporation in all the States and New Zealand will, owing to the absence of a Federal Companies Act, occupy a considerable time, but the new rules will apply as soon as adopted. Members will be notified early of the result of the ballot on 17th December.

SUBSCRIPTIONS.

The attention of any members whose subscriptions may be in arrears is urgently directed to Article 8 of the proposed new Constitution which it is anticipated will be in operation after 17th December, 1920:

> Article 8—"All Members, Associate Members and Students of the unincorporated Australasian Institute of Mining and Metallurgy automatically become members of the same class of membership in the Institute on incorporation, *on payment of arrears*, if any, due to the unincorporated Australasian Institute of Mining and Metallurgy."

MOVEMENTS OF MEMBERS.

Charles A. Banks is now managing director of the British Canadian Silver Corporation Ltd. His address is 5 Nelson Court, Vancouver, B.C. Mr. Banks enlisted for active service in January, 1916. He attained the rank of Captain. Most of his work at the front was in connection with tunnelling (mainly at Messines). He was demobilised in April, 1919.

E. H. Blakemore, of Sydney (Member of Council), is on a visit to America.

C. F. Courtney (Member of Council), general manager of the Sulphide Corporation Ltd., is visiting London. He left Australia in September by the R.M.S. Orvieto.

H. Herman, of Melbourne (Member of Council), has resigned as Director of Geological Survey, Victoria, to fill the position of engineer in charge of briquetting and brown coal by-products research work under the Electricity Commission, Victoria.

Eric W. Hughes has returned to Australia. He won one of the Soldier Scholarships presented by Mr. Otto Biet, and subsequently graduated as an Associate of the Royal School of Mines (London).

Wm. J. McBride, of the Broken Hill South Ltd., is visiting the Bawdwin Mines of the Burma Corporation Ltd. He will be absent from Australia for three or four months.

Oluf Moen, late of St. Bathans, Otago, N.Z., has been appointed overseer of the Lake Monowai Construction Works for the Southland Electric Power Board. His address is P.O., Riverton, Southland, N.Z.

C. Lonsdale Smith is now managing the Cherry Tin Mine, Ardlethan, N.S.W. He was formerly manager of the Tungsten Mines Ltd., Frogmore, N.S.W.

Mr. Hector Stewart, M.C.E., F.C.S., has been commissioned to report exhaustively on the Westralian and the Premier Coal Mines and activities and on the East Collie Coal Mining, Briquetting and By-products Ltd. properties.

E. Hogan Taylor, late general manager Great Cobar Ltd., has been appointed general manager of the New Guinea Copper Mines, Laloki, Papua.

George J. Twine, who during the war was on service in England as Chemist on Explosives, has returned to Australia and is now works manager and chemist to the Queensland Cement and Lime Company at Darra, Queensland.

L. V. Waterhouse, late of Mount Lyell M. & R. Coy., Queenstown, Tasmania, has been appointed general manager of the Mount Hope Ltd., N.S.W.

REPORTS OF BRANCHES.

A meeting of the Broken Hill Branch was held on 13th July, when a paper entitled "The Scope of the Engineer in the Great War," by O. B. Williams, was read.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY

From 30th June, 1920 to 30th September, 1920.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
Department of Mines, Victoria : Geological Survey, Records, Vol. IV, Parts 1 and 2		Melbourne
Royal Society of Victoria : Proceedings, Vol XXXII., Part 2		Melbourne
Department of Mines, Queensland : Geological Survey, Publications, No. 268		Brisbane
Royal Society of Queensland : Proceedings, Vol. XXXI.		Brisbane
School of Mines, Adelaide : Prospectus 1919 and Annual Report 1920		Adelaide

Institution of Engineers of Australia (Adelaide Division):
  Artesian Well Boring Plant and Machinery, by A. E. Smith
  Modern Lathes, by W. L. Burton - - Adelaide
Institution of Mining and Metallurgy:
  Bulletins, Nos. 189 and 190 - - London
Institution of Mining Engineers:
  Transactions, Vol. LIX., Part 3 - - London
Geological Society:
  Quarterly Journal No. 299 - - - London
Department of Scientific and Industrial Research:
  Second Report of the Mine Rescue Apparatus Research Committee
  Report of the Fuel Research Board for the Years 1918 and 1919 - - - - London
Société des Ingenieurs Civils de France:
  Bulletin, Oct. and Dec. 1919 - - Paris
Annales des Mines:
  Vol. X., 1920 - - - - Paris
Mining and Geological Institute of India:
  Transactions, Vol. XIV., Part 2 - - Calcutta
Geological Survey of India:
  Records, Vol. LI., Part 1 - - - Calcutta
Mysore Geological Department:
  Bulletin No. 9 - - - - Bangalore
Department of Mines and Geology, Mysore:
  Records, Vol. XVII., Part II. - - Bangalore
Department of Mines, Canada:
  Summary Report of the Mines Branch, 1919, Parts B, D and G
  Memoirs, 115-117
  Bulletin, No. 31 - - - - Ottawa
Munition Resources Commission, Canada:
  Final Report of the Work of the Commission, 1920 - - - - - Toronto
American Institute of Mining and Metallurgical Engineers:
  Mining and Metallurgy, Nos. 163 and 164 - New York

Maryland Geological Survey :
  Volume X., 1918
  Anne Arundel County (with maps)
  Cretaceous—Upper (Text)
  Cretaceous—Upper (Text and Plates) - Baltimore
United States Geological Survey :
  Water Supply Papers, 411, 422, 427, 436, 450A
  Bulletins Nos. 44, 668, 669, 676, 677, 683, 685, 687, 688, 690, 691-E,K,F,L,M, 693, 698, 711A
  Mineral Resources, Various Papers, 1916-1918
  Professional Papers, 104, 107, 109, 110, 112, 114, 120, 121 - - - - Washington
Cuerpo de Ingenieros de Minas :
  Boletin No. 96 - - - - Lima
Department of Mines, Mexico :
  Boletin Minero, Vol. IX., Nos. 1 and 2 - - Mexico

RECENT ARTICLES ON MINING MATTERS.

(30th June, 1920, to 30th September, 1920).

Note.—This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining, engineering, metallurgy, &c., due regard being had to Australasian requirements.

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian and Mining Standard*, Melbourne, Victoria, wk., 6d.
(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.
(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.
(4) *The Mining Journal*, London, E.C., wk., 6d.
(5) *Mining and Engineering World*, Chicago, wk., 10c.
(6) *The Engineering and Mining Journal*, New York, wk., 15c.
(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.
(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.
(9) *Annales des Mines*, Paris, France, mth.
(10) *Publications*, Department of Mines, Melbourne, Victoria.
(11) *Publications*, Department of Mines, Sydney, New South Wales.
(12) *Publications*, Department of Mines, Adelaide, South Australia.
(13) *Publications*, Department of Mines, Brisbane, Queensland.
(14) *Publications*, Department of Mines, Perth, Western Australia.
(15) *Publications*, Department of Mines, Hobart, Tasmania.
(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.
(17) *Publications*, Bureau of Mines, Toronto, Ontario.
(18) *Publications*, Geological Survey of India, Calcutta.
(19) *Publications*, Geological Survey, U.S.A., Washington.
(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.
(21) *Publications*, California State Mining Bureau, Sacramento, Cal.
(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.
(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.
(24) *Quarterly Journal*, Geological Society, London.
(25) *Transactions*, Inst. Mining and Metallurgy, London, E.C.
(26) *Transactions*, Inst. Min. Eng., London.
(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.
(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.
(29) *Transactions*, Am. Inst. of Min. & Met. Eng., New York City.
(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.
(31) *Journal*, Franklin Inst., Philadelphia, Pa.
(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.
(33) *Transactions*, Am. Soc. C.E., New York City.
(34) *Bulletins*, Société des Ingénieurs Civils, Paris.
(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.
(36) *Publications*, Iron and Steel Institute, London.
(37) *Proceedings*, Inst. of Mech. Eng., London.
(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.
(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.
(40) *Transactions*, Mining and Geological Institute of India, Calcutta.
(41) *Publications*, Department of Mines, Wellington, N.Z.
(42) *Journal*, Chamber of Mines of West Australia, Perth.
(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

GEOLOGICAL.

Some Features of the Geological Department of the Anaconda Copper Mining Co. P. Billingsley. (8) June 19, 1920.

Lateral Distribution of Metallic Minerals. J. D. Kendall. (35) Aug., 1920.

The Nickel-Copper Mines of Sudbury. Dr. J. Mackintosh Bell. (35) Aug., 1920.

The Discovery of Fossils in the Grampian Sandstones, with General Notes on the Formation. W. H. Ferguson. (10) Records, Vol. IV., Part 1.

Geology of the Nowa Nowa District. W. H. Ferguson. (10) Records, Vol. IV., Part 2.

A Geological Reconnaissance of the Country between Laverton and the South Australian Border. H. W. B. Talbot and E. de C. Clarke. (14) Bull. No. 75.

MECHANICAL.

Standardization of Hose Fittings for Hammer Rock Drills. G. H. Gilman. (6) June 6, 1920.

Air Lift for Mine Drainage. S. F. Shaw. (6) June 5, 1920.

Design of Two-Bucket Aerial Tramway. D. Lay. (6) June 19, 1920.

Unwatering by Air Lift in Grass Valley, California. G. J. Young. (6) July 10, 1920.

Handling Broken Rock Ore Chunks. H. H. Hunner. (6) July 17, 1920.

The Theory of the Centrifugal Fan. W. S. Weeks. (8) June 12, 1920.

Centrifugal Pumps. R. S. Lewis. (8) July 17, 1920.

Mechanical Stoker Tests. D. Brownlie. (37) March, 1920.

METALLURGICAL.

Flotation of Molybdenite at Empire, Col. W. Coghill and J. P. Bonardi. (6) May 29, 1920.

A Cyanide Plant without Frills. L. A. Palmer. (6) June 5, 1920.

Metallurgical Plants in the Vicinity of New York. E. H. Robie. (6) June 12, 1920.

Assaying Quicksilver Ores. R. G. Place. (6) June 12, 1920.

Developing a Mill Flow-Sheet at Morenci, Ariz. A. Crowfoot and E. Wittenan. (6) June 19, 1920.

A High Temperature Oil-Fired Laboratory Furnace. H. K. Najarian. (6) June 26, 1920.

Electrical Precipitation of Cyanide Solutions. D. Lay. (6) July 10, 1920.

Charts for Computing Blast-Furnace Performances. H. L. Fickett. (6) July 17, 1920.

Time-Saving Devices in an Assay Office. F. L. Smith. (6) July 17, 1920.

Oxygen in Cyanide Solutions. E. M. Hamilton. (6) July 17, 1920.

Feed Product Size Diagram. G. J. Young. (6) July 17, 1920.

Recent Metallurgy at Trail, British Columbia. F. H. Mason. (8) June 12, 1920.

A Volumetric Method for Determination of Tungsten. G. M. Enos. (8) June 12, 1920.

Smelting Cyanide Precipitate. (8) June 2, 1920.

The Fahrenwald Flotation Machine. F. A. Thomson. (8) July 12, 1920.

Some Observations on Smelting. H. H. S. (8) July 19, 1920.

The Dorr Bowl-Classifier. H. Hanson. (8) June 19, 1920.

Some Observations on Smelting. C. W. Tandy. (8) July 10, 1920.

Electrolytic Separation of Copper from a Copper-Cobalt-Nickel Matte. R. G. Knickerbocker. (8) July 10, 1920.

Pulverized Coal in Metallurgical Furnaces at Cerro de Pasco. O. L. M'Intyre. (8) July 10, 1920.

Initial Velocity of Bubbles in a Pneumatic Flotation Cell. M. S. Donaldson. (8) July 26, 1920.

The Analysis of Magnesite. W. C. Riddell. (8) July 26, 1920.

Concentration of Magnetite Ore. (8) July 24, 1920.

Electro-Metallurgy of Manganese Ore. (8) July 24, 1920.

Flotation Mill Runs and Laboratory Tests. F. G. Moses. (8) Aug. 14, 1920.

The Flue Type of Cottrell Treater. A. B. Young. (8) Aug. 21, 1920.

Electro-Deposition of Gold and Silver from Cyanide Solution. J. E. Clennell. (35) July, 1920.

Hydro-Metallurgy of Gold and Silver. H. Freeman. (2) July 15, 1920.

The Determination of Zirconium in Steel. G. E. F. Lundell and H. B. Knowles. (43) June 1, 1920.

The Application of the Rotating Zinc Reductor in the Determination of Molybdenum. W. Scott. (43) June 1, 1920.

A Rapid Determination of Sulphuric Acid in Commercial Sulphuric Acid. A. A. Kohr. (43) June 1, 1920.

The Production of Phosphoric Acid by Smelting Phosphate Rock in a Fuel-Fed Furnace. W. H. Waggaman and T. B. Turley. (43) July 1, 1920.

Investigations on Zirconium. J. W. Marden and M. N. Rich. (43) July 1, 1920.

Method for the Determination of Thiocyanates in Ammoniacal Liquor from Ammonia Stills in the By-product Coking Industry. J. A. Shaw. (43) July 1, 1920.

Rapid Determination of Small Amounts of Copper by the Iodide Method. H. F. Bailey. (43 Aug. 1, 1920.

MINING

An Improved Wedge for Deflecting Diamond Drills. C. E. Wuensch. (8) June 26, 1920.

New Hoisting Equipment at the Tonopah Extension Mine. (8) Aug. 21, 1920.

Coal Mining Dangers: New Regulations under the British Act. (2) Sept. 15, 1920.

MISCELLANEOUS.

Waste Materials in the Mining Industry. G. T. Harley. (6) June 12, 1920.

Welfare Work at the Homestake Mine. B. C. Yates. (6) July 31, 1920.

Mr. Govett on the Gold Problem. (8) June 5, 1920.

The Measurement of Ventilating Air. W. S. Weeks. (8) July 19, 1920.

The Testing and Application of Ventilating Fans. W. S. Weeks. (8) July 13, 1920.

The Price of Gold. A. Moline. (8) June 26, 1920.

Federated American Engineering Societies. (8) June 26, 1920.

The Price of Gold. T. French. (8) July 24, 1920.

Problems in Mine Ventilation. W. S. Weeks. (8) July 24, 1920.

A History of Mine Fires in the South-West: Part I. C. A. Mitke. (8) Serial commenced July 31, 1920.

Science and Industry. A. W. Allen. (8) July 31, 1920.

Signalling Mine Hoists from Moving Cages. C. A. Allen. (8) Aug. 14, 1920.

Systematising Large Mine Examinations. M. Webber. (8) Aug. 14, 1920.

Curves of Ore Valuation. K. K. Hood. (8) Aug. 21, 1920.

The Hampton Plains Discoveries. C. M. Harris and L. R. Benjamin. (35) May, 1920.

Apparatus for the Improvement of the Power Factor in Mining Electrical Machinery. A. W. Ashton. (26) Vol. LIX., Part 3.

Antimony in 1917. E. S. Bastin. (19) Mineral Resources, 1917, Part 1.

Iron Ore, Pig Iron, and Steel in 1917. E. F. Burchard. (19) Mineral Resources, 1917, Part 1.

Cobalt, Molybdenum, Nickel, Titanium, Tungsten, Radium, Uranium, and Vanadium in 1916. F. L. Hess. (15) Mineral Resources, 1916, Part 1.

Gold, Silver, Copper, Lead, and Zinc in Montana in 1917. V. C. Heikes. (15) Mineral Resources, 1917, Part 1.

Gold, Silver, Copper, Lead, and Zinc in Nevada in 1917. V. C. Heikes. (15) Mineral Resources, 1917, Part 1.

Gold, Silver, Copper, Lead, and Zinc in California and Oregon in 1917. C. G. Yale. (15) Mineral Resources, 1917, Part 1.

Gold, Silver, Copper, Lead, and Zinc in Utah in 1917. V. C. Heikes. (15) Mineral Resources, 1917, Part 1.

Gold, Silver, Copper, and Lead in South Dakota and Wyoming in 1917. C. W. Henderson. (15) Mineral Resources, 1917, Part 1.

Arsenic, Bismuth, Selenium, and Tellurium in 1918. J. M. Hill. (15) Mineral Resources, 1918, Part 1.

Magnesite in 1918. R. W. Stone. (15) Mineral Resources, 1918, Part 1.

Cadmium in 1918. C. E. Siebenthal. (15) Mineral Resources, 1918, Part 1.

Quicksilver in 1917. F. L. Ransome. (15) Mineral Resources, 1917, Part 1.

Gold, Silver, Copper, Lead, and Zinc in Idaho and Washington in 1917. G. N. Gerry. (15) Mineral Resources, 1917, Part 1.

Gold, Silver, Copper, Lead, and Zinc in Arizona in 1917. V. C. Heikes. (15) Mineral Resources, 1917, Part 1.

Quicksilver in 1916. H. D. McCaskey. (15) Mineral Resources, 1916, Part 1.

Zinc and Cadmium in 1916. C. E. Siebenthal. (15) Mineral Resources, 1916, Part 1.

Lead in 1916. C. E. Siebenthal. (15) Mineral Resources, 1916, Part 1.

Fuel Briquetting in 1918. C. E. Lesher. (15) Mineral Resources, 1918, Part 2.

Sand-Lime in Bricks in 1918. J. Middleton. (15) Mineral Resources, 1918, Part 2.
Sodium Salts in 1917. R. C. Wells. (15) Mineral Resources, 1917, Part 2.
Cement in 1917. E. F. Burshard. (15) Mineral Resources, 1917, Part 2.
Clay-Working Industries, &c., in 1917. J. Middleton. (15) Mineral Resources, 1917, Part 2.
Lime in 1917. G. F. Louglin. (15) Mineral Resources, 1917, Part 2.
Petroleum in 1917. J. D. Northrop. (15) Mineral Resources, 1917, Part 2.
Coal in 1917. C. E. Lester. (15) Mineral Resources, 1917, Part 2.
Pyrenees Proprietary Mine, Redbank. W. Baragwanath. (10) Records, Vol. IV., Part 1.
Notes on Bealiba. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Wolfram at Lintons. W. Baragwanath. (10) Records, Vol. IV., Part 1.
The Prince of Wales Gold Mine, Wehla. A. M. Howitt. (10) Records, Vol. IV., Part 1.
Patten's Mine, Brown's Reef, Evansford. H. S. Whitelaw. (10) Records, Vol. IV., Part 1.
The Yankee Doodle Reef, Goldsbrough. A. M. Howitt. (10) Records, Vol. IV., Part 1.
Auriferous Reefs near Talbot. H. S. Whitelaw. (10) Records, Vol. IV., Part 1.
The Golden Reef, Dereel. E. J. Dunn. (10) Records, Vol. IV., Part 1.
The Matrix Reef, M'Intyre's, near Rheola. H. S. Whitelaw. (10) Records, Vol. IV., Part 1.
The Clunes Goldfield. W. Baragwanath. (10) Records, Vol. IV., Part 1.
Forrester's Mine, Smeaton. W. Baragwanath. (10) Records, Vol. IV., Part 1.
Dean's Marsh Coal Mine. Stanley Hunter. (10) Records, Vol. IV., Part 1.
The Lord Tennyson Reef, Welshman's Gully, Eganstown, near Daylesford. A. M. Howitt. (10) Records, Vol. IV., Part 1.
The Golden Hope Mine, near Blakeville. W. H. Ferguson. (10) Records, Vol. IV., Part 1.
Alleged Occurrence of Mineral Oil at Anglesea. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Magnesite and Clay at Spring Creek, Rowsley, near Bacchus Marsh. D. J. Mahony. (10) Records, Vol. IV., Part 1.
Notes on the District Embracing Diamond Hill and Adelaide Gully, Castlemaine. H. S. Whitelaw. (10) Records, Vol. IV., Part 1.
The South Wattle Gully Mine, Chewton. W. Baragwanath. (10) Records, Vol. IV., Part 1.
Magnesite at Heathcote. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Infusorial Earth near Mickleham. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Iron Ore at Mount Major. (10) Records, Vol. IV., Part 1.
The Luck's All Gold Mine, Enoch's Point. O. A. L. Whitelaw. (10) Records, Vol. IV., Part 1.
The Star and Thomson Gold Mine, Aberfeldy. A. M. Howitt. (10) Records, Vol. IV., Part 1.
The East Walhalla Copper and Platinum Mine. A. M. Howitt. (10) Records, Vol. IV., Part 1.
The Mammoth Lode, Gibbo River. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Silver Lodes, Omeo. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Some Iron Ore Deposits in South Gippsland. E. J. Dunn. (10) Records, Vol. IV., Part 1.
Limestone at Aringa, near Port Fairy. W. H. Ferguson. (10) Records, Vol. IV., Part 2.
Limestone at Garvoc. L. H. Ower. (10) Records, Vol. IV., Part 2.
Matrix Reef, M'Intyre's. E. J. Dunn. (10) Records, Vol. IV., Part 2.
Bass and Watson's Gold-Wolfram Mine, Linton. H. Herman. (10) Records, Vol. IV., Part 2.
Some Mines at Scarsdale. W. Baragwanath. (10) Records, Vol. IV., Part 2.
Smeaton Reserve United Mine. W. Baragwanath. (10) Records, Vol. IV., Part 2.
Brown and Black Coal near Winchelsea. H. Herman. (10) Records, Vol. IV., Part 2.
Some Mines at Daylesford. H. S. Whitelaw. (10) Records, Vol. IV., Part 2.
O'Connor's Mine, Drummond North. W. Baragwanath. (10) Records, Vol. IV., Part 2.
New Red, White and Blue United Mine, Bendigo. H. S. Whitelaw. (10) Records, Vol. IV., Part 2.
Diamond Creek Gold Mine, Nillumbik. A. M. Howitt. (10) Records, Vol. IV., Part 2.
Tyrell's Reef, Black Range, Edi. A. M. Howitt. (10) Records, Vol. IV., Part 2.
Phosphate of Iron and Other Minerals, Whitfield District. A. M. Howitt. (10) Records, Vol. IV., Part 2.
The Indigo Pioneer Mine, Indigo Creek. J. P. L. Kenny. (10) Records, Vol. IV., Part 2.
Archer's Wolfram Mine, Indigo Creek. J. P. L. Kenny. (10) Records, Vol. IV., Part 2.
The Chiltern Golden Bar Mine. J. P. L. Kenny. (10) Records, Vol. IV., Part 2.
The Lady Rose Mine, Chiltern. J. P. L. Kenny. (10) Records, Vol. IV., Part 2.
Royal George Tin Mine, Mitta Mitta. J. P. L. Kenny. (10) Records, Vol. IV., Part 2.
The Victory Mine, Glen Wills. J. P. L. Kenny. (10) Records, Vol. IV., Part 2.
Iron Ore at Nowa Nowa and Mount Tara. O. A. L. Whitelaw. (10) Records, Vol. IV., Part 2.
Recent Mining in Croajingolong. H. Herman. (10) Records, Vol. IV., Part 2.

The Gold Premium. S. Evans. (28) May, 1920. Discussion: June, 1920.
Salt: Article 1 in Industrial Minerals. B. Dunstan. (13) Geol. Survey Publication No. 268.
Asbestos: Article 2 in Industrial Minerals. B. Dunstan. (13) Geol. Survey Publication No. 268.
Mica: Article 3 in Industrial Minerals. B. Dunstan. (13) Geol. Survey Publication No. 268.
The Normanby Goldfield. C. C. Morton. (2) July 15, 1920.
Mount Oxide Copper Mine, Cloncurry. B. Dunstan. (2) July 15, 1920.
Explosives in Mines. (2) Aug. 14, 1920.
Coal-Washing by Froth Lubrication. (2) Sept. 15, 1920.
The P.P. Shot-Firing Appliances. (2) Sept. 15, 1920.
Pulverized Fuels. A. Montgomery. (42) June 30, 1920.
Graphite. Hugh S. Spence. (17) Mines Branch, No. 511.

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PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy.

NEW SERIES.

No. 40.

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

31st DECEMBER, 1920.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY, MELBOURNE.

Australasian Institute of Mining and Metallurgy.

LIST OF OFFICERS, 1920.

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R. W. Chapman, S.A.

Vice-Presidents:

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George C. Klug, W.A.
Colin Fraser, S.A.

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A. A. Boyd	Queensland
W. E. Wainwright	New South Wales
James Hebbard	New South Wales
G. H. Blakemore	New South Wales
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H. Herman	Victoria
E. W. Skeats	Victoria
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G. D. Delprat	New South Wales
Richard Hamilton	Western Australia
A. S. Kenyon	Victoria
Geo H. Broome	Victoria
George Weir	New South Wales
J. W. Sutherland	Western Australia

Secretary:

D. L. Stirling, Melbourne, Vic.

LOCAL CORRESPONDENTS:

South Australia	R. W. Chapman, Adelaide.
New South Wales	F. Danvers Power, Sydney.
Western Australia	F. W. R. Godden, Hampton Plains.
New Zealand	D. B. Waters, Dunedin.
Tasmania	Russell M. Murray, Mount Lyell.
North Queensland	Murray Russell, Brisbane.

BRANCH SECRETARIES:

Sydney	F. Danvers Power, 33-39 Hunter Street, Sydney, N.S.W.
Kalgoorlie	F. W. R. Godden, Hampton Plains.
Broken Hill	C. H. J. Clayton, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. Patterson, Mount Morgan, Q.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

18 Queen Street, Melbourne, Victoria.

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Institute Matters.

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MINUTES OF MEETINGS.

OF THE INSTITUTE.

First Ordinary Meeting, 17th December, 1920.—1 p.m.

Mr. George Weir in the chair.

The Secretary read the notice convening the meeting.

Minutes of the Annual Meeting held on 30th January, 1920, were confirmed.

The chairman appointed Messrs. A. D. Mackay, Gerald Young, and Wm. Baragwanath scrutineers to examine ballots on the question of the adoption of the Memorandum and Articles of Association as per resolution contained in Circular No. 5.

The scrutineers reported that the ballot paper showed that members voting were unanimously in favor of the adoption of the Memorandum and Articles of Association.

The chairman then declared the adoption of the New Constitution, and subscribed the Memorandum and also the Articles of Association for the purpose of identification.

OF THE EXECUTIVE COMMITTEE.

(Summary.)

OCTOBER 6TH, 1920—1 P.M. (Special Meeting).

Resolved that the Annual Meeting be held on Friday, January 31st, but, if the new Rules were adopted at the Ordinary Meeting on 17th December, the Annual Meeting be held in March, as provided by new Rules.

Delegates were appointed on the Council of the Hobart Meeting of the Australasian Association for the advancement of Science.

Resolved that opinions of all Members of Council be obtained on the question of the eligibility of mining and metallurgical accountants as Members and Associate Members.

NOVEMBER 1ST, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £79 passed for payment.

Leave of absence from Council Meetings was granted to Mr. Colin Fraser to enable him to visit New Zealand.

Nomination of Mr. James Conway as a member was submitted and consideration thereof deferred. Nomination of Mr. J. A. Dunn as an Associate Member was approved.

The following were admitted to the Institute as members:—Messrs. L. Venn Brown, W. H. Campbell, Josiah Crabb, George Dey, Alex. Robt. Graham, Joseph Grigg, C. Sidney Honman, Wm. Parsonage, Goiders Walls, and Peter Joseph Walsh. As Associate Members—Messrs. Wm. T. Anderson, Wilfred Ray Broad, Richard Gardiner Casey, Gordon Escott Gabriel, Harold F. Pearson, and Harry Vernon Pethebridge. Transfer from Associate Member to Member—Mr. Victor Arnold Haig. As Student—Mr. R. G. Colman.

A paper by Mr. W. H. Corbould, entitled "A Proposed Copper Metallurgical Process," was submitted and referred to the Publication Committee.

The allocation of the Donation Fund was deferred pending the acceptance of the new Constitution.

The advisability of co-operating with the Institution of Engineers of Australia in the matter of the registration of Engineers was discussed.

NOVEMBER 29TH, 1920—1 P.M.

The Secretary's report was presented and accounts to the amount of £17 passed for payment.

Resolved that War Savings Certificates maturing on 15th December remain in Commonwealth Bank for safe custody.

Applications for admission to the Institute from the following were approved ;—As Members—Messrs. William Ernest Barron, Percy Rawlings Osborne, and William Nelson Cranz. As Associate Members—Messrs. William Gray, John Noall, and Charles George Lanfear Thompson.

Opinions of a number of members of Council in respect to the suggestion that Accountants of large mining and metallurgical corporations be admitted to the Institute were submitted, but decision thereon was deferred pending replies from all members.

In regard to a memorandum from the Broken Hill Branch on the subject of legislation in New Zealand concerning the withdrawal from use of reciprocating rock drills and the possible introduction of such legislation in the Australian States, it was resolved that enquiry be made and steps be taken, if necessary, to oppose the compulsory adoption of any particular kind of drill. The opinion was expressed that, provided a satisfactory result was obtained and conditions fulfilled, the choice of drill should be left entirely to the management.

Direction was given regarding the issue of final notice to members in arrears of subscriptions.

Other routine business was transacted.

DECEMBER 22ND, 1920—1 P.M.

The chairman of the First Ordinary Meeting held on 17th inst., reported that members had decided unanimously by ballot to adopt the new Constitution. Directions were then given in regard to notifying members by circulars of this fact.

Five subscribers to the Memorandum of Association, in accordance with the Companies Act, were nominated.

Resolved that the Annual Meeting, 1921, be held on 21st March in accordance with Article 85.

An Executive Committee was appointed as provided in Article 61.

Standing Committees were also appointed.

The Secretary's report was presented and accounts to the amount of £143, including Printing, £82, salaries and accommodation, £50, were passed for payment.

Resolved that Mr. C. C. Klug be appointed to represent the Institute on the Engineering Faculty, Melbourne University, subject to his acceptance.

It was reported that Mr. J. A. Dunn (Student Member) had been appointed a Frecheville Fellow of the Royal School of Mines for Research into Relation existing between Country Rocks and Enclosed Deposits.

The nomination of Mr. Loftus Hills as a member was approved, also that of Mr. E. E. G. Boyd as an Associate Member.

The resignation of Mr. R. Bert Millett, on account of his having severed his connection with the mining industry, was accepted.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holiays.

MEMBERSHIP.

Since the last issue of Proceedings, the following have been admitted to the Institute:—

Members.

Names and Addresses.

BROWN, LIONEL VENN, Ocean House, Moore Street, Sydney, N.S.W.
CAMPBELL, WILLIAM HORACE, c/o Broken Hill Associated Smelters Ltd., Port Pirie, S.A.
CRABB, JOSIAH, Southern Cross, W.A.
DEY, GEORGE, Balmoral Road, Port Pirie, S.A.
GRAHAM, ALEXANDER ROBERT, State Coal Mine, Wonthaggi, Vic.
GRIGG, JOSEPH, Sungei Lembing, Pahang, Federated Malay States.
HONMAN, C. SIDNEY, Hannan's Club, Kalgoorlie, W.A.
PAROSNAGE, WILLIAM, State Coal Mines, Runanga, Greymouth, N.Z.
WALLS, GOIDERS, Devenport West, Tas.
WALSH, PETER JOSEPH, c/o Broken Hill Associated Smelters Ltd., Port Pirie, S.A.

Transfer from Associate Member to Member.

HAIG, VICTOR ARNOLD, Broken Hill Proprietary Block 10 Ltd., Broken Hill, N.S.W.

Associate Members.

ANDERSON, WILLIAM THOMAS, "Clifton," Ben Boyd Road, Neutral Bay, Sydney, N.S.W.
BROAD, WILFRED RAY, British Broken Hill Proprietary Co., Broken Hill, N.S.W.
CASEY, RICHARD GARDINER, 125 William Street, Melbourne, Vic.
GABRIEL, GORDON ESCOTT, 327 Bromide Street, Broken Hill, N.S.W.
GARNETT, ROBERT KAY, 554 Chapple Street, Broken Hill, N.S.W.
PEARSON, HAROLD FORD, 288 Oxide Street, Broken Hill, N.S.W.
PETHEBRIDGE, HARRY VERNON, Main Road, Moonah, Hobart, Tas.

Student.

COLMAN, WILLIAM R. G., Upper Sturt, S.A.

Applications for admission to the Institute have been received from the following:—As Members—William Ernest Barron, Rhodesia, Broken Hill D. Co., Broken Hill or Rhodesia; William Nelson Cranz, c/o Broken Hill Proprietary Ltd., Broken Hill, N.S.W.; Loftus Hills, Geological Survey Office, Launceston, Tas. As Associate Members—Eric Ewart Gladstone Boyd, Queenstown, Tas.; William Gray, Anglo-Persian Oil Co., c/o Whitten Bros., Port Moresby, Papua; John Noall, c/o Pahang Consolidated Co. Ltd., Sungei Lembing, Kuantan, Singapore, Fed. Malay States; Percy Rawlings Osborne, Port Moresby, Papua; Charles George Lanfear Thompson, c/o New Guinea Copper Mines Ltd., Port Moresby, Papua.

PUBLICATIONS.

The following paper is included in this issue:—

Treatment of Wolfram, Bismuth and Molybdenite Ores at Burma-Queensland Corporation Mill, Wolfram, Queensland. By W. H. Bowater.

NEW CONSTITUTION.

As reported by circular No. 6 the ballot for the adoption of the new constitution took place at the ordinary meeting, held on 17th December, and resulted in the unanimous adoption of the Memorandum and Articles of Association. Application for registration was immediately made, and it is anticipated that a certificate of incorporation will very shortly be granted.

ANNUAL MEETING, 1921.

The Annual Meeting, 1921, will, in accordance with the new constitution (Articles 37 & 35), be held on 21st March. The business of the meeting will include the presentation of the Annual Report and Balance-Sheet, and the election of Auditor.

FRECHEVILLE FELLOWSHIP.

The Institute was notified during December that Mr. J. A. Dunn (Student) had been appointed a Frecheville Fellow of the Royal School of Mines, the nature of the research work he is expected to carry out being the relation between country rocks and enclosed deposits. Particulars of this Fellowship were supplied by the Aus. I. M. M. to all members and to Mining Schools throughout Australasia.

LOCAL CORRESPONDENT.

Mr. W. G. Langford has been appointed Local Correspondent for Papua. His address is Vailala Oil Fields, Papua.

MOVEMENTS OF MEMBERS.

W. Baragwanath now occupies the position of Director of Geological Survey of Victoria. He was formerly Senior Field Geologist, and has been Acting Director since the retirement of Mr. H. Herman.

B. V. Barton has been appointed Mining Superintendent of the Bendigo Amalgamated Goldfields during the absence of the General Manager, Mr. A. H. P. Moline.

Gordon L. A. Ditchburn, formerly of the Pahang Consolidated, is now with the Yukon Dredging Co., 16 Loke Yew Bldgs, Kuala Lumpur, F.M.S.

H. Herman, formerly Director of Geological Survey, Victoria, and now Engineer for Briquetting, Victorian Electricity Commission, will shortly visit Germany for the purpose of purchasing briquetting plant to operate at Morwell, Vic.

G. Mc I. Hunter severed his connection with the Central Mine, Broken Hill, to take up a position with the Electrolytic Zinc Co. of Australasia Ltd., Risdon, Hobart, Tas.

A. C. Julius has left the C.S.A. Mine, Cobar, and is now at the Ottery Mine, Tent Hill, N.S.W.

Arthur Moline, General Manager of the Bendigo Amalgamated Goldfields, N.Z., is visiting America.

Leslie H. Ower, of the Mines Dept., Melbourne, has accepted a position with the Imperial Government to take charge of the Geological Survey of British Honduras.

H. Rickleman, of the Electrolytic Refining and Smelting Co., Port Kembla, N.S.W., has returned from a visit to America.

J. B. Shaw has returned to Australia. His address is c/o The Union Bank of Australia, Pitt Street, Sydney.

H. S. Weigall, who retired from the Army in May last with the rank of Lieut.-Colonel, is now General Manager of the Taio Gold Mining Co., Ltd., Nakatsue Mura, Hida Gun, Oita Ken, Kyushu. Japan.

D. Yates is with the Broken Hill Proprietary Co. Ltd., Newcastle, N.S.W. He enlisted with the First Australian Tunnelling Co., and attained the rank of Captain.

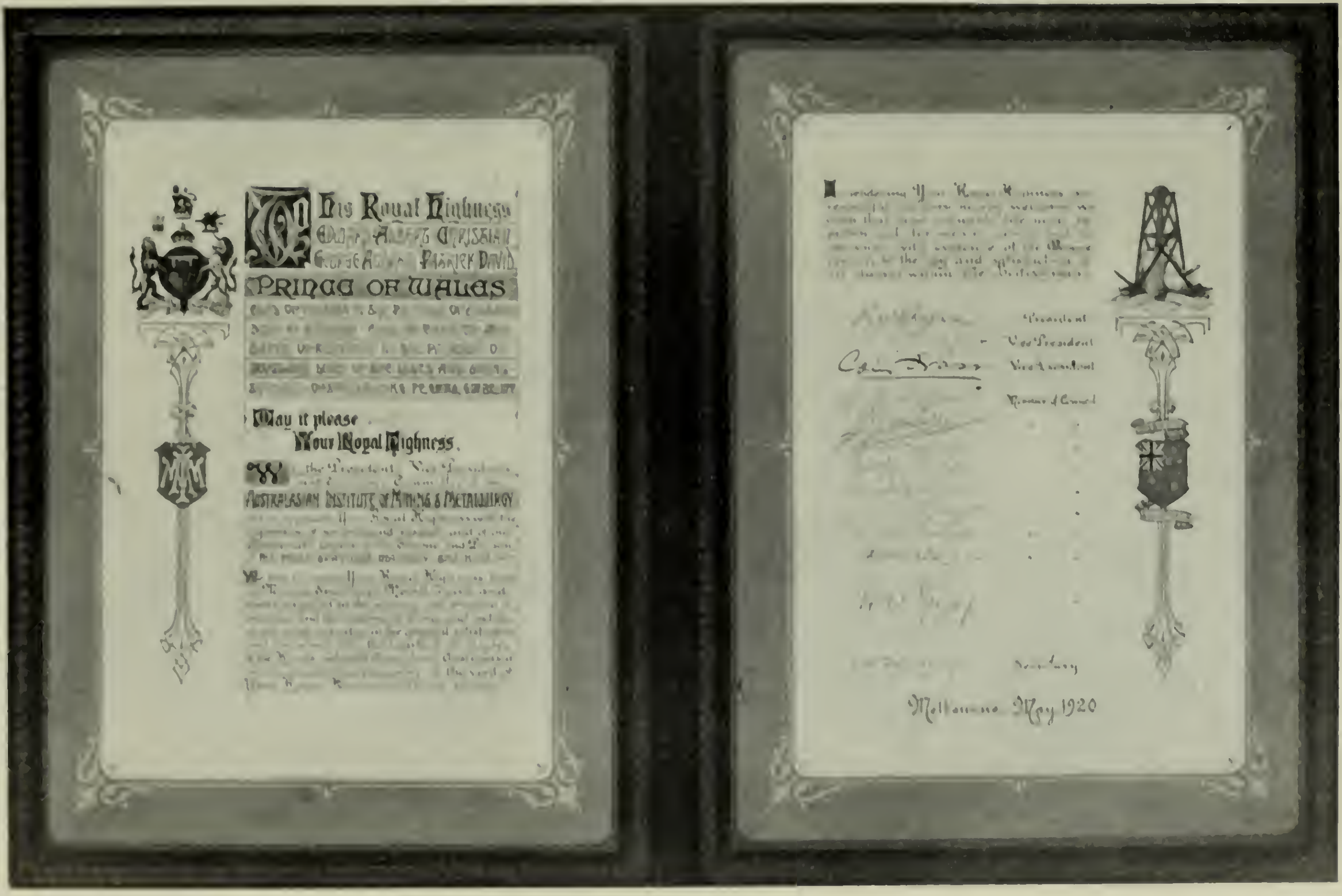
OBITUARY.

Maurice Osric Copland (Member), B.M.E., principal of the Ballarat School of Mines and Technical School, died on July 31st, at the age of 40 years, after a short illness. He was a graduate of the Melbourne University, and had practical experience in mining in the Walhalla district (V), on the Rand, and in Western Australia. Going from the Kalgoorlie School of Mines to Ballarat, about four years ago, Mr. Copland took great interest in experiments to test the suitability of Victorian clays for the manufacture of white earthenware. He gave enthusiastic assistance in the establishment of repatriation classes at the Ballarat School of Mines.

Philip a'M. Parker (Associate Member) B.C.E., died at Kuala Lumpur, Federated Malay States, on 4th August, 1920. Mr. Parker left Australia some years ago to occupy a position with the firm of J. A. Russell & Co., of Kuala Lumpur. He was with that firm at the time of his death.

VISIT OF THE PRINCE OF WALES.

During the visit of the Prince of Wales to Australia, an address of welcome, on behalf of the Institute, was presented to His Royal Highness. A photo of the address, which was of exquisite coloring and design, is reproduced herewith. The following acknowledgment, on behalf of the Prince, was subsequently received :—



To His Royal Highness
Edward Albert Christian
George Andrew Patrick David
Prince of Wales

May it please
Your Royal Highness.

We the President, Vice-Presidents
Australasian Institute of Mining & Metallurgy

President
Vice-President
Vice-President
Members of Council
Secretary

Melbourne May 1920

REPRODUCTION OF ILLUMINATED ADDRESS TO H.R.H. PRINCE OF WALES.

Melbourne,
28th May, 1920.

The President,
Australasian Institute of Mining and Metallurgy.

Sir,

I am directed by the Prince of Wales to convey to you his sincere thanks for the loyal address of welcome presented by you yesterday on behalf of the Australasian Institute of Mining and Metallurgy. His Royal Highness is very sensible of the important service done by the mining engineers and metallurgists of the British Empire. and knows that they have played an important part in developing the mineral wealth of Australia. He thanks you for your good wishes, and will be happy to convey your assurances of devotion to His Majesty the King.

I am,
Your obedient servant,
(Sgd.) E. W. M. GRIGG,
Lieut. Colonel,
Secretary to H.R.H. the Prince of Wales.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY
FROM 30TH SEPTEMBER, 1920 TO 31ST DECEMBER, 1920.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
University of Melbourne : Calendar, 1921		Melbourne
Department of Mines, New South Wales : Records, Vol. IX., Part IV.		Sydney
Department of Education : Technical Gazette, Vol. X., Part I		Sydney
Institution of Engineers of Australia (Adelaide Division) : Tramway Permanent Way Construction, by J. Bowman Recent Developments in Electrical Engineering Practice in the United States, by J. R. Brookman		Adelaide

Department of Mines, South Australia :	
Mining Review for Half-Year ended June 30, 1920 -	Adelaide
Department of Mines, Queensland :	
Annual Report, 1919 - - -	
Geological Survey, Publications, No. 269 -	Brisbane
Department of Mines, Western Australia :	
Report on the Manganese Deposits at Horseshoe Range, Peak Hill Goldfield, by A. Montgomery	Perth
Department of Mines, Tasmania :	
Annual Report, 1919 - - -	Hobart
New Zealand Institute :	
Transactions and Proceedings, Vol., LII. -	Wellington
Department of Mines, New Zealand :	
Geological Survey, Bulletin, No. 21 - -	Wellington
New Zealand Journal of Science and Technology :	
Journal, No. 4 , - - -	Wellington
Institution of Mining and Metallurgy :	
Bulletins, Nos. 181-194 - - -	London
Institution of Mining Engineers :	
Transactions, Vol. LIX., Parts 4 and 5 -	London
Geological Society :	
Quarterly Journal Nos. 300 and 301 - -	London
Geologists' Association :	
Proceedings, Vol. XXXI., Part 3 - -	London
Société des Ingeneiurs Civils de France :	
Memoires, 8th Series, Nos. 1, 2 and 3 -	Paris
Annales des Mines :	
Vol. IX., Part 6, Vol. X., Parts 7 and 8 -	Paris
Mining and Geological Institute of India :	
Transactions, Vol. XV., Part 1 - -	Calcutta
Geological Survey of Alabama :	
Bulletin, Nos. 19-22	
Special Report, No. 11 - - -	Alabama
Department of Mines, Ontario :	
Annual Report, Vol. XXIX., Part 3- -	Toronto
American Institute of Mining and Metallurgical Engineers :	
Bulletin, Nos. 165 and 166 - - -	New York
California State Mining Bureau :	
Bulletin, Nos. 85 and 87 - -- -	Sacramento

RECENT ARTICLES ON MINING MATTERS.

(30th September, 1920, to 31st December, 1920).

Note.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c., due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Transactions*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng., New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

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The Geology of the Wolfram Lodes of the West of England. E. H. Davison. (35) Oct., 1920.

The Bearing of the Distribution of Certain Metallic Minerals on their Genesis. J. D. Kendall. (35) Nov., 1920.

Dominant Features Controlling Ore Deposits of Washington. E. N. Patty. (6) Sept. 4, 1920.

The Origin of Primary Ore Deposits. J. M. Campbell. (26) Bull. No. 193.

Small Gasteropoda from the Lower Cretaceous of Queensland. R. Etheridge. (13) Pub. No. 269.

Geology of Middle Waipara and Weka Pass District. J. Allan Thomson. (23) Vol. LII.

Report on the Manganese Deposits at Horseshoe Range, Peak Hill Goldfield. A. Montgomery. (14) 1920.

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Modern Coal-Pulverizing Plant at United Verde. J. B. Johnson. (6) Aug. 21, 1920.

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Hoisting Equipment at Utah Apex Mining Co. J. A. Norden and A. R. Willson. (6) Sept. 4, 1920.

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Pumping Water. Prof. F. C. Lea. (26) Vol. IX., Part 5.

Grinding Valves with a Breast Drill. C. Nye. (6) Oct. 2, 1920.

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A New High-Speed Turbo Compressor. B. Gore. (6) Oct. 9, 1920.

An Automatic Counting Machine for Checking Tram Wagons. C. Brackenbury. (26) Bull. No. 194.

Recent Excavator Practice. F. H. Livens and W. Barnes. (37) Oct., 1920.

Road Transport by Steam Vehicles. P. W. Robson. (37) Oct., 1920.

Some Lincolnshire Oil Engines. F. H. Livens. (37) Oct., 1920.

The Uniflow Steam Engine. F. B. Perry. (37) Oct., 1920.

Wire Ropes Research. W. A. Scoble. (37) Nov., 1920.

Helical Springs. W. N. Thomas. (37) Nov., 1920.

Prism Hardness. B. P. Haigh. (37) Nov., 1920.

The Measurement of High Degrees of Hardness. John Innes. (37) Nov., 1920.

Hardness Testing. H. S. Primrose and J. S. G. Primrose. (37) Nov., 1920.

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The Electrification of the Works and Collieries of the Ebbw Vale Steel, Iron and Coal Co. Ltd. W. Dixon. (36) Sept., 1920.

Temper-Brittleness of Nickel Chromium Steels. R. H. Greaves and J. J. A. Jones. (36) Sept., 1920.

The Constitution of the Nickel-Iron Alloys. D. Hanson and H. E. Hanson. (36) Sept., 1920.

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An Investigation of Various Forging Operations Carried Out Under Hydraulic Presses. E. Shneider. (36) Sept., 1920.

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The Desulphurizing Action of Hydrogen on Coke. A. R. Powell. (43) Nov., 1920.

Determination of Molybdenum. (8) Sept. 4, 1920.

Roasting and Chloridizing of Bolivian Silver-Tin Ores. M. G. F. Sohnlein. (8) Sept. 11, 1920.

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The Application of the Bradford Process to Mixed Sulphide Concentrates. W. D. Green and W. Fagergren. (8) Sept. 25, 1920.

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The United Verde Smelters. L. A. Parsons. (8) Oct. 16, 1920.

Pebble-Mill Grinding and Amalgamation. (6) Aug. 28, 1920.

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Leaching and Concentrating Mixed Copper Ores. A. Crowfoot and K. H. Donaldson. (6) Sept. 4, 1920.

The Economics of Blast-Furnace Charging. C. A. Grabill. (6) Sept. 11, 1920.

Ball Tests on Missouri Lead Ore. L. A. Delano and H. Rabling. (6) Sept. 18, 1920.

Krupp Mills v. Rolls for 10-Mesh Grinding. (6) Sept. 18, 1920.

Selecting a Slag and Apportioning Slag Losses. C. A. Grabill. (6) Sept. 18, 1920.

Classifier Efficiency. R. T. Hancock. (6) Sept. 25, 1920.

The Manufacture of White Arsenic. E. C. Williams. (6) Oct. 2, 1920.

The Shattuck-Arizona Mill for Concentrating Silver-Lead Carbonate Ores. G. L. Allen. (6) Oct. 16, 1920.

Converting High-Grade Matte in Magnesite-Lined Converters. H. C. Robson. (26) Bull. No. 194.

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The Cost of Mining as Influenced by Poor Development. A. G. Wolf. (6) Sept. 18, 1920.

Diamond Drilling as a Means of Intensive Development. P. S. Couldrey and E. H. S. Sampson. (6) Sept. 25, 1920.

Calculation of Unit Smelting Costs and Values. C. A. Grabill. (6) Sept. 25, 1920.

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NOTES ON THE WORK OF AN AUSTRALIAN TUNNELLING COMPANY IN FRANCE.

BY O. H. WOODWARD.

FOREWORD.

IT is intended in this paper to present in broad outline to the members of the Institute a short account of the conditions and operations that constitute what is variously known as Subterranean Warfare, Military Mining, or Tunnelling.

Realizing the magnitude of the operations, and the varied and minute details met with in them on the Western Front, it is the writer's intention to confine these notes to operations carried out by the First Australian Tunnelling Company. In so doing there is no wish to detract from the very fine records of the Second and Third companies It is to be hoped that members of the Institute (or others) who were with these companies will write accounts of their doings—the former in the water-logged areas to the south of Armentiéres, and later in the sand-dunes at Lombardzee, and the latter in the chalk area of the Lens coal-

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[This paper is separately bound, and may be, if so desired, detached complete from this number.]

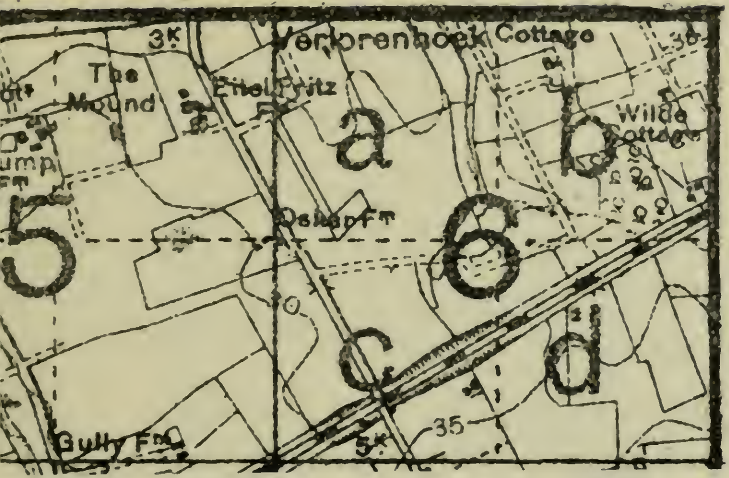
field. The conditions under which these companies worked were very different from those of the First Tunnelling Company, and it would be presumptuous for an officer of any individual company to attempt to describe the operations of all three.

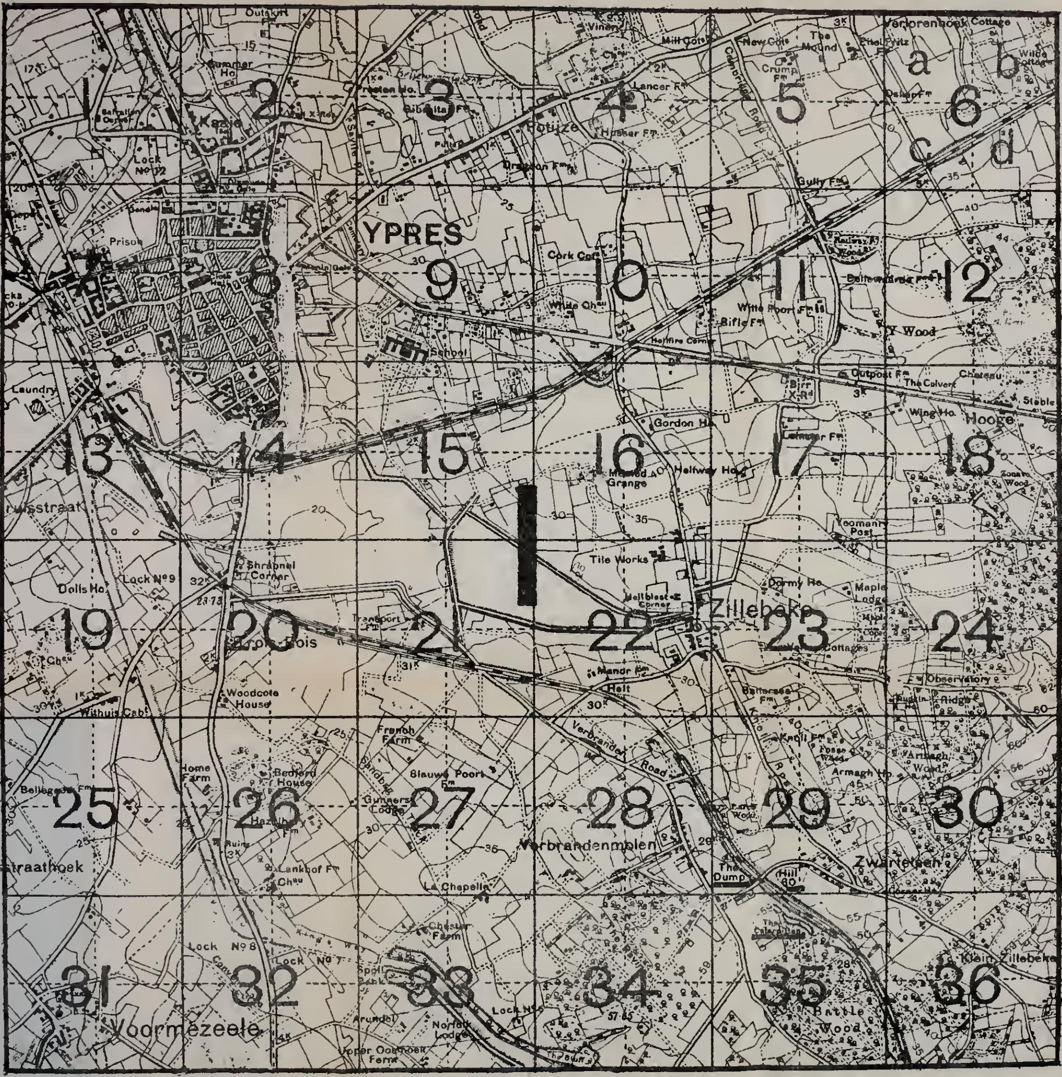
HISTORICAL.

The student of the Great War is forced to realize that "the spade and the power of the spade have played a leading part from the very first day." It was very early in the war that General Lemain had to cut trenches across the sectors between the Liége forts. Trench warfare may be said to have commenced in deadly earnest after the battle of the Aisne. Once this phase of warfare had been reached conditions began somewhat to resemble fortress warfare. We find that all points possessing natural tactical advantages in that practically continuous line of trench from the flats of Western Flanders into Alsace, to within sight of the Rhine, were converted into veritable fortresses by the enemy. As the result of this, and to cope with his advantageous position, the Allies commenced their mining operations on a very elementary scale compared to that into which they eventually evolved. It was about the middle of 1915 that the Imperial authorities accepted Australia's offer to send over mining men. The establishment of the Mining Corps was the result.

This corps was in active training in the latter part of 1915 under the command of Lieut.-Col. A. C. Fewtrell, with Major T. W. E. David as Officer in Charge of the Technical Headquarters Staff.

The corps embarked at Sydney on 20th February, 1916, and landed at Marseilles on 5th May, where it entrained and finally reached Hazebrouck on 8th May. On arriving at Hazebrouck the corps came under the administration of the Controller of Mines of the Second Army B.E.F. It was then found that the establishment of our corps did not conform to that of existing tunnelling units on the western front. To conform with these, we found that we had to forfeit our status as a corps. Lieut.-Col. Fewtrell was transferred to an A.I.F. Pioneer Battalion as C.O.,


3K
The Mound
Eitel Fritz
Verlorenhoek Cottage
36
Wilde Cottage
a
b
5
6
Oskar Fm
c
d
35
5K
Gully Fm



LOCALITY MAP—HILL 60 AREA

SCALE—1 : 20,000.

Metres 1000 0

Yards 1000 0

and Major David to general headquarters, where he took charge of the whole of the geological work of the British army ; and the three companies comprising the corps were formed into separate companies, operating entirely under the control of the Mines Department.

No. 1 company was allotted the sector on either side of the River Lys, from Ploegstraat Wood on the north to Houplines on the south, with headquarters at Armentiéres.

No. 2 company was allotted the sector in the water-logged area to the south of Armentiéres, with headquarters at Sailly.

No. 3 company was allotted the chalk area in the Lens coalfield, with headquarters at Neux la Mines.

The three companies were actively engaged in military mining by 15th May, 1916.

From this date reference will be made only to the work of the First Tunnelling Company, A.I.F.

From the 15th May to 26th May the company was attached to the First Canadian Tunnelling Company for instruction in underground warfare. On the 27th May it assumed control of mining operations on the front extending from Ploegstraat Wood to Houplines—a distance of about three miles. The operations were largely confined to defensive mining, though in Ploegstraat Wood a combination of offensive and defensive mining was in operation, with large mines under the German positions at Factory Farm and The Birdcage.

The company remained on this sector until the end of October, 1916, when it was moved north and relieved the Third Canadian Tunnelling Company at that historic spot, Hill 60. It speaks well for the Australian miners that, after such a short apprenticeship, the Higher Command could entrust them with the care of one of the largest and most important mining systems on the western front. Here we remained until after the battle of Messines Ridge, in June, 1917, which practically ended the mining operations of the Second Army B.E.F. Hill 60 had such a sinister reputation that tunnelling companies generally remained for only six months on the work. However, as the handing over of such a mining system as that existing here was a difficult task, and not without risk to the safety of the system, our company remained in charge until the mines were fired.

It is not the wish of this company to claim more than a fair share of the success of these mines. The credit lies with every tunnelling company which, at various times from 1914 to 1917, had control of the system. The excellent supervision of the Mines Department of the army resulted in a continuity of operations which culminated in an awe-inspiring explosion at 3.10 a.m. on 7th June, 1917. At this hour the formidable fortress of Hill 60 was blotted out, and that well-remembered and well-hated Ypres salient ceased to exist.

There is little doubt that the rapidity with which the German fortress area on the Messines Ridge fell into our hands can be laid to the credit of the tunnelling companies, with their 19 mines charged with over 600 tons of high explosive.

After the cessation of active mining in 1917 the tunnelling companies were allotted duties similar to those of the field companies of engineers and Pioneer battalions; but these operations are not within the scope of the present article.

TUNNELLING COMPANY ORGANIZATION.

The original establishment of a tunnelling company was 360, all ranks. Later it was increased to 750, all ranks. This was the reason why the 4th, 5th, and 6th tunnelling companies were absorbed by the 1st, 2nd, and 3rd companies respectively.

Command.	Rank.
Officer Commanding	Major.
Second in Command	Captain.
Adjutant and Quartermaster	Captain.
Officers commanding sections	Captain.
Section officers	Lieutenants.
Section Sergeants	Staff Sergeant.
Squad Sergeants	Sergeants.

Each section was an independent unit, with a strength of one captain, three lieutenants, and 170 other ranks.

When operating as a whole, as in Hill 60, the company was divided into a right and left half-company, two sections in each; one half-company operating in the trenches and the other resting and training in headquarters camp. The tour of duty in the trenches was for four days, and each section comprising the half-company in the line relieved each other every six hours.

Military Mining.

Military mining may be divided into two sections, though the line of demarcation is never really clearly defined.

Section 1, *Defensive Mining.*—As the name implies, this class of mining aims chiefly at the construction of an underground mine-system with the primary object of protecting our own system of defence-works. The section of trench to be defended is chiefly governed by information gained of the enemy's operations by aeroplane photos. and by careful watching of his front with the aid of the periscope. The transition from a system of defence-mining to a combination of defensive and offensive mining depends solely on the operations of the enemy, provided, of course, that our own tactical requirements do not call for offensive mining.

Briefly stated, defensive mining consists of constructing a main lateral gallery running approximately parallel to our own front trench, and situated in "No-Man's Land" at such a distance as to prevent mines having effect on the trench system proper.

From several points in the front line trench or communication trenches, shafts (either vertical or inclined) were sunk at from 100 to 200 ft. intervals, and from them drives were put out towards the enemy lines. These drives were then connected by crosscuts, which formed the main lateral gallery. Then at intervals of about 50 ft. listening posts were driven off this main lateral gallery towards the enemy lines and carried out to such a distance as to ensure the protection of the main lateral from the effect of enemy blows. When this point was reached the listening post was driven at right angles to the left and right, and these T heads were carried towards each other to ensure that the area between should be under control by a counter mine fired from either listening post. Generally, to further ensure this, four holes about 8 in. diam. were put in to carry a charge of from 100 to 200 lb. of high explosive placed in a torpedo.

The depth of this defence system in Flanders was governed by the water-level, and was usually about 18 ft., leaving a head cover of from 14 ft. to 15 ft.

The morale of all troops is greatly affected by enemy mines being blown under their trench system, even though with shallow mines the result obtained may not be greater than an enemy shell of large calibre.

Fig. 1 gives the lay-out of a theoretical system of defensive mining.

Section 2, Offensive Mining.—Offensive mining has for its aims the penetration of the enemy's line and the laying of charges under important tactical positions of such size as to completely wreck them and form craters for the attacking infantry to consolidate.

It naturally follows that depth is an essential to the production of craters of large dimensions and to a large horizontal area of rupture. With offensive mining it is always essential to have a defensive system above ground-water level, and it is general —as was the case at Hill 60—to establish an intermediate level between the defensive and deep offensive systems. This level is referred to as "the fighting level," and it is generally attempted to confine counter-mining to this level in order to mask the work in the deep offensive level. This plan of attack proved highly successful at Hill 60, as information since gained shows that the enemy did not suspect the existence of the deep mining system until too late.

General Mining Tactics.—Broadly speaking, these very closely resembled the fighting tactics of above-ground offensive tactics. Case I. :—Having blown the enemy in a position previously located by means of careful listening, all effort is made to recover the portion of our own damaged gallery (the result of the blow), and to drive forward, skirting the disturbed ground, with the aim of reaching the enemy gallery before he has organized for its recovery. In this case the initiative is in our hands, and considerable time may be gained. Case II.:—In the event of an enemy blow wrecking our own gallery, the object is to rapidly

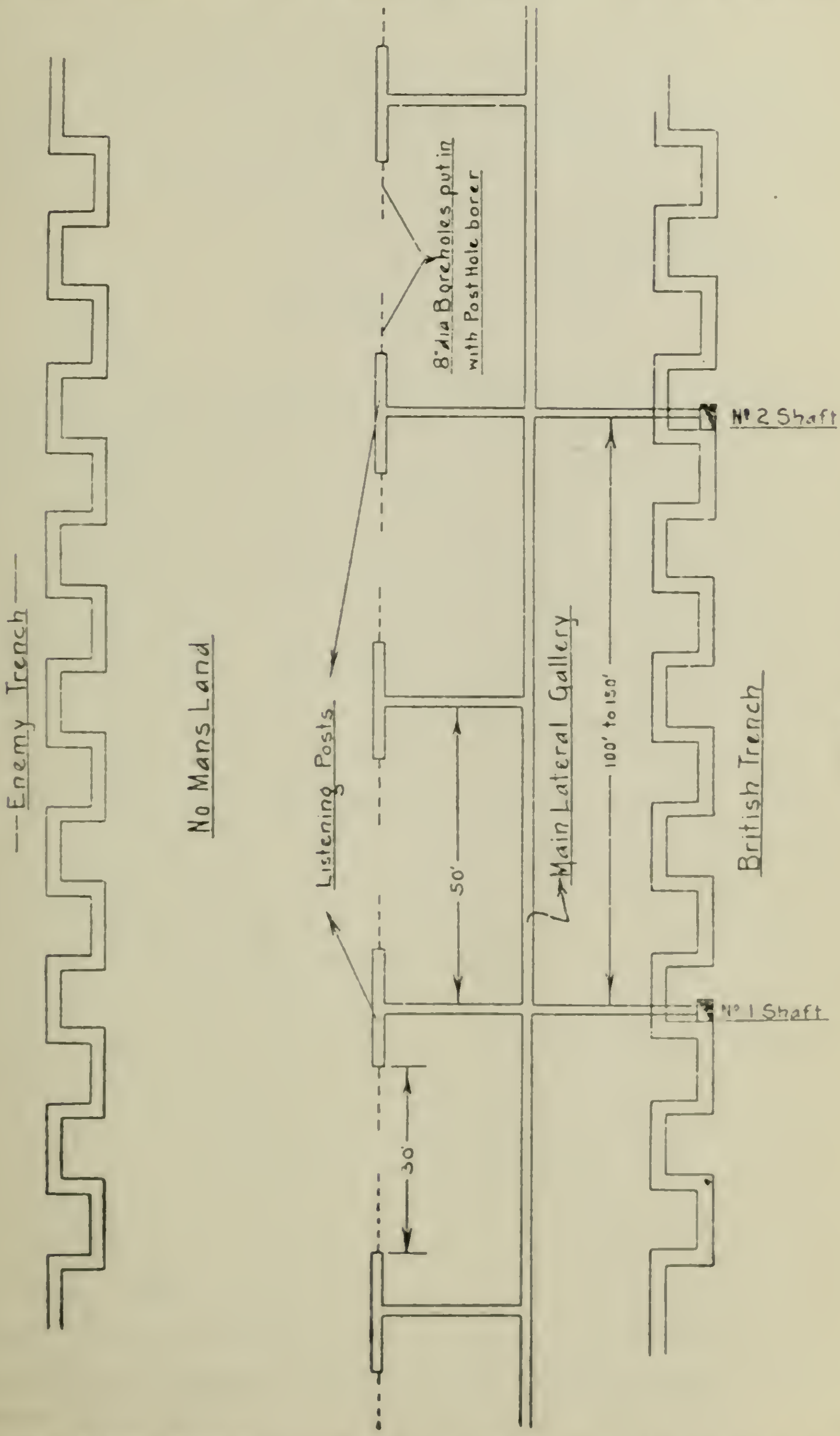


FIG. 1.
IDEAL LAY-OUT OF DEFENSIVE MINING SYSTEM.

form an intermediate lateral gallery behind the disturbed zone, in order to prevent the enemy getting through. This accomplished, the next step is to drive a new gallery and attempt to reach the area in which the enemy had blown.

Briefly, Case I. can be likened to storming the enemy position and Case II. to forming a support line, and from there attempting to recover the lost ground.

HILL 60.—DESCRIPTIVE.

There is not a battalion in the British army that does not know the heap of mud rising on the left of the Ypres–Menin railway line, where that line passes through the Zandvoorde ridge. This eminence derived the name of Hill 60 from the fact that the 60-metre contour line surrounded the crest. In relation to the surrounding country it can scarcely be designated a hill, but it was just sufficiently high to dominate the Ypres salient and obscure our view of the enemy's back areas. Hill 60 lies about 2½ miles in a south-easterly direction from the historic town of Ypres, and almost at the apex of the famous Ypres salient.

Two other artificial mounds of earth rise in this area, both on the right-hand side of the railway cutting. The first, The Caterpillar—so called from its resemblance to that insect when seen on an aerial photo.—lay entirely in the enemy lines, and the other, The Dump, lay in ours. These were formed by the spoil from the railway cutting, which is about 30 ft. deep. The Ypres salient was a most dreaded spot to all troops, as in most sectors of its front the enemy could shell from practically three sides. It was the scene of some of the most bitter fighting of the war, and it saw the first use of poison gas by the enemy. The enemy at all points dominated our back areas, and troops moving in and out of our trenches had to do so under cover of darkness.

From its position it was never a rest-home, and when our official reports recorded "all quiet on the western front," it could be assumed without exception that this did not apply to the Ypres salient. It may justly be described as a vast mangled graveyard.

GEOLOGY.

All tunnelling companies were supplied with accurate geological data compiled by Lieut.-Col. T. W. E. David and his staff. This data was a valuable guide in mining operations, as by it

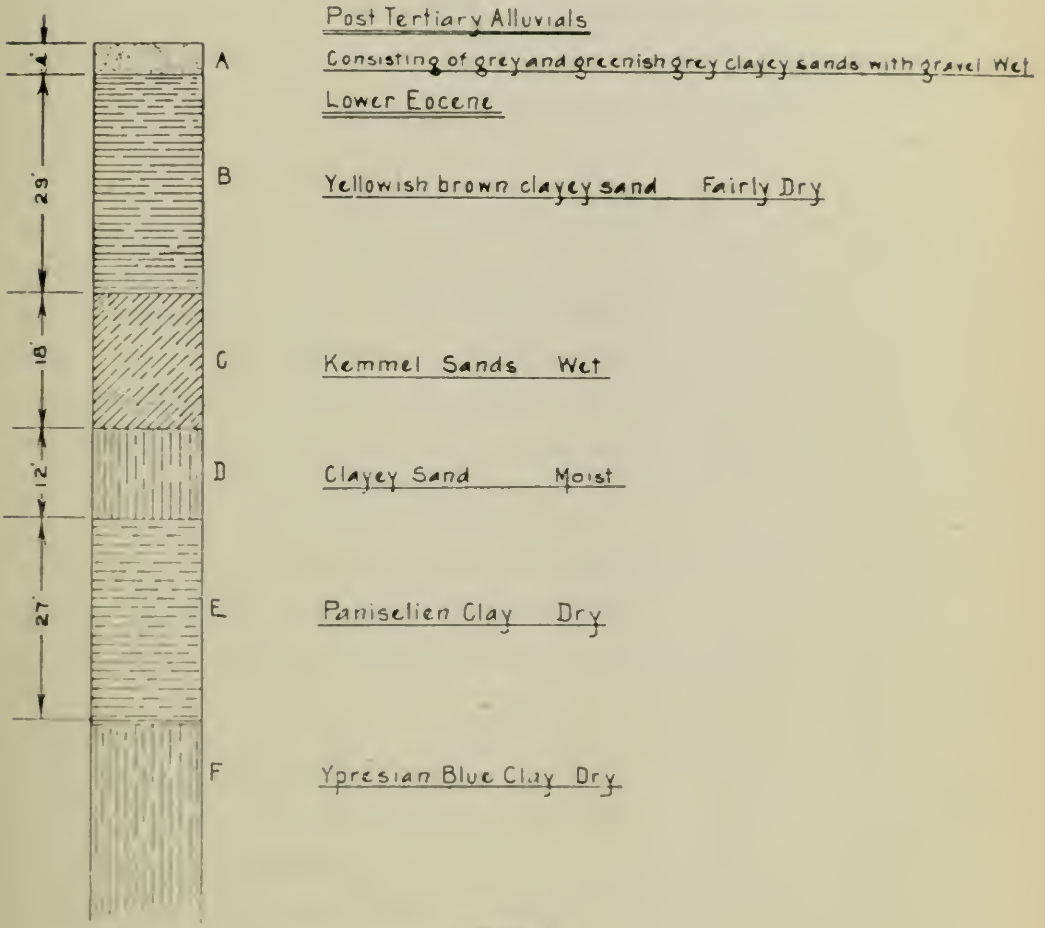


FIG. 2.

IDEAL GEOLOGICAL SECTION—HILL 60.

the variation of winter and summer level of the underground water was shown. By this means the depth to which offensive galleries could be sunk without fear of striking water-bearing zone could be estimated. In its geological structure Hill 60 was composed entirely of sedimentaries, and an ideal section is as shown in Fig. 2.

A.—*Post Tertiary* alluvials, "Campinien," consisting of grey sands and greenish-grey clayey sands with gravel: this bed wet.

Lower Eocene.

B.—29 ft., yellowish-brown clayey sand: fairly dry.

C.—18 ft., Kemmel sands: wet.

D.—12 ft., clayey sand: moist.

E.—27 ft., Paniselien clay: dry.

F.—(?) Ypresian blue clay: dry.

Mining Operations, Hill 60.

Hill 60 was the scene of some of the earliest if not actually the first mining warfare. With the opening of the spring campaign of 1915, one of the first British movements was an attack on this Hill. We took it and lost it again, and thereafter each side commenced mining operations in deadly earnest. Unfortunately, the writer is unable to give a list of the various English tunnelling companies whose wonderful efforts pioneered the way to the ultimate grand success of the operations there.

In May, 1916, the Third Canadian Tunnelling Company took over this sector, and to that company is due the credit of having carefully laid the two mines—one under Hill 60 and the other under The Caterpillar.

Not being in possession of the plans of the Hill 60 mining system, it is necessary to attempt to describe its essential details.

Reference to direction will be made in relation to the railway cutting looking towards the enemy lines (see map, Plate 1).

Commencing in Bensham Road—our immediate support line—and about 50 ft. from the railway cutting, a main adit 6 ft. 3 in. by 3 ft. 6in. in the clear, and parallel to the railway cutting, was driven for a length of 300 ft., having at this point head-cover of approximately 20 ft. Here a shaft-chamber was excavated, and the main Berlin sap commenced. This sap was the main incline shaft of the system, and was driven for 570 ft. at an average dip of 12° from the horizontal. This point was approximately directly under the enemy front trench.

From here a drive was put in at an angle of about half-left for a length of 240 ft., which brought the end of the drive under the crown of Hill 60. From the same point at the foot of the Berlin sap another drive at a direction half-right was put in for a distance of 510 ft., bringing the end of the drive immediately below the centre of The Caterpillar. In this drive the Canadians experienced trouble, and had to step down about 10 ft. in order to get clear of a band of quicksand. In consequence this mine was under water from the time of charging until it was fired some months later. It speaks well for the careful work of the Canadians that it withstood the long inundation.

At a level about 40 ft. below the surface, and running to the left of the railway cutting and well out under "No-Man's Land," was driven the main intermediate level. This ran for about 400 ft., and formed the main fighting level of the system.

A system of defensive galleries extended from the railway cutting for a distance of about 1000 ft., and approximately parallel to our front line trench. Five shafts connected the front line trenches with this system.

On the arrival of the First Australian Tunnelling Company a deeper system of offensive mining was commenced. From the level of the top of the Berlin sap a vertical shaft was sunk to a depth of 90 ft. This was the first vertical shaft sunk on the Hill 60 system, though not the first attempted.

From this shaft, known as the Sydney, a gallery 500 ft. in length was driven and connected with the foot of the Berlin sap. A pipe-line was installed to convey all the drainage from the old system to the sump of the Sydney shaft, whence it was pumped by an electrically-driven geared pump. The shaft chamber was made as sound-proof as possible. From the Sydney drive, and about 250 ft. from the shaft, a drive to the left, known as Brisbane gallery, was driven for 800 ft., the object being to lay a mine under a German strong post known as The Snout.

From the same position in the Sydney gallery the Perth gallery was driven, with the object of laying a mine under another portion of The Caterpillar. This gallery was driven for a length of 500 ft.

Neither of these mines was completed, although the work was within five weeks of completion. The tactical situation and the danger of the enemy locating the Hill 60 mine decided the higher authorities to precipitate the attack.

On the right of the cutting we had a defensive mining system protecting about 500 ft. of our front trench system.

The activity of mining operations on this sector may be judged by the fact that 34 mines were fired in the 12 months prior to the attack.

During the last few weeks prior to the attack the enemy was particularly active. He seemed to be vainly searching for our deep mines, and seemed to blow at random in the hope of destroying our work.

How close he came to success may be judged by the fact that a mine blown on 25th May crumpled the gallery leading to Hill 60 charge, entombed a listener for 48 hours, and broke one set of the leads to the mine. About 150 ft. of the tamping had to be removed in order to repair the damaged lead.

This gave us a very advanced listening post, and we were much disturbed to hear the enemy actively working in very close proximity to the main charge. A creaking windlass enabled us to measure his progress in shaft-sinking, and at about the end of May the turns of this windlass were constant, so it was safe to assume that he was driving a gallery towards us, and very nearly on the same level as ours.

As the zero day approached we had to retamp our gallery and trust to luck. Needless to say, those were most anxious days, and practically continuous continuity and resistance tests were made on the Hill 60 leads in order to have earliest information of their being interfered with.

Our luck held, and at 10 minutes past 3 o'clock on the morning of 7th June the switch was thrown over. The earth lifted and rose in two heaving mounds, gently sank back, and as it receded the gases hissed out from countless cracks and burst into two huge tongues of flame.

To those of us who were anticipating the spectacle it was fearsome, and one wonders what were the sensations of the very few of the enemy who escaped from such a hell on earth.

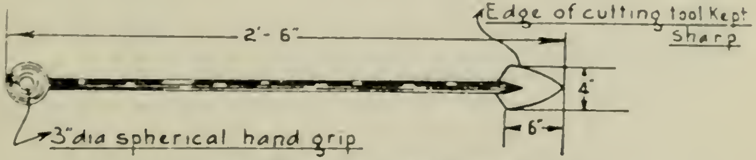
MINING METHODS.

The actual excavation of the earth was governed by the tactical conditions—

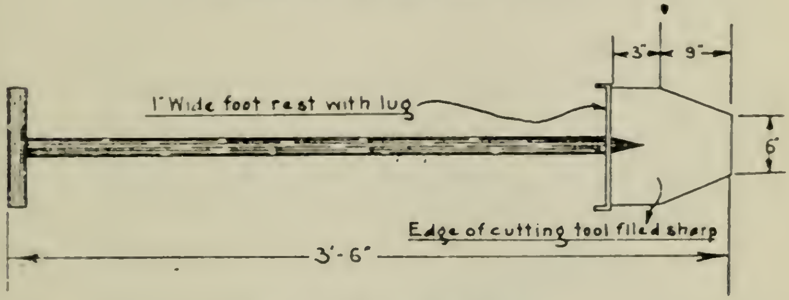
(*a*) Defensive or offensive mining.

(*b*) Dugout construction and main infantry subways.

In (*a*) silence was absolutely essential, so that the use of the pick as a means of excavation was prohibited. This was overcome by the employment of one of two methods—(1) with the push-pick or grafting tool, an illustration of which is given in Fig. 3.



PUSH-PICK OR GRAFTING TOOL.



CLAY-KICKING SPADE.

FIG. 3.

This method was almost universally employed in galleries where a minimum of noise was essential. The pick was pushed into the clay, the spherical end giving good control, and the clay caught in the hand and placed in sand-bags.

It is fairly evident that this method is slow but sure when feeling the way to suspected enemy galleries. Under such conditions a progress of 4 to 6 ft. per 24 hours was satisfactory when cessation of operations for listening purposes is taken into account.

(2) Clay-kicking.—This, to the Australians, was a distinct innovation, and they were not slow to grasp its great advantages. It originated with the sewerage-construction workers in the clay beds of London, and for silence accompanied by speedy progress is unequalled.

Briefly, the operation of clay-kicking can be described as a method whereby the whole of the power given to the clay-kicking spade (see Fig. 3) is supplied by the legs, the operator

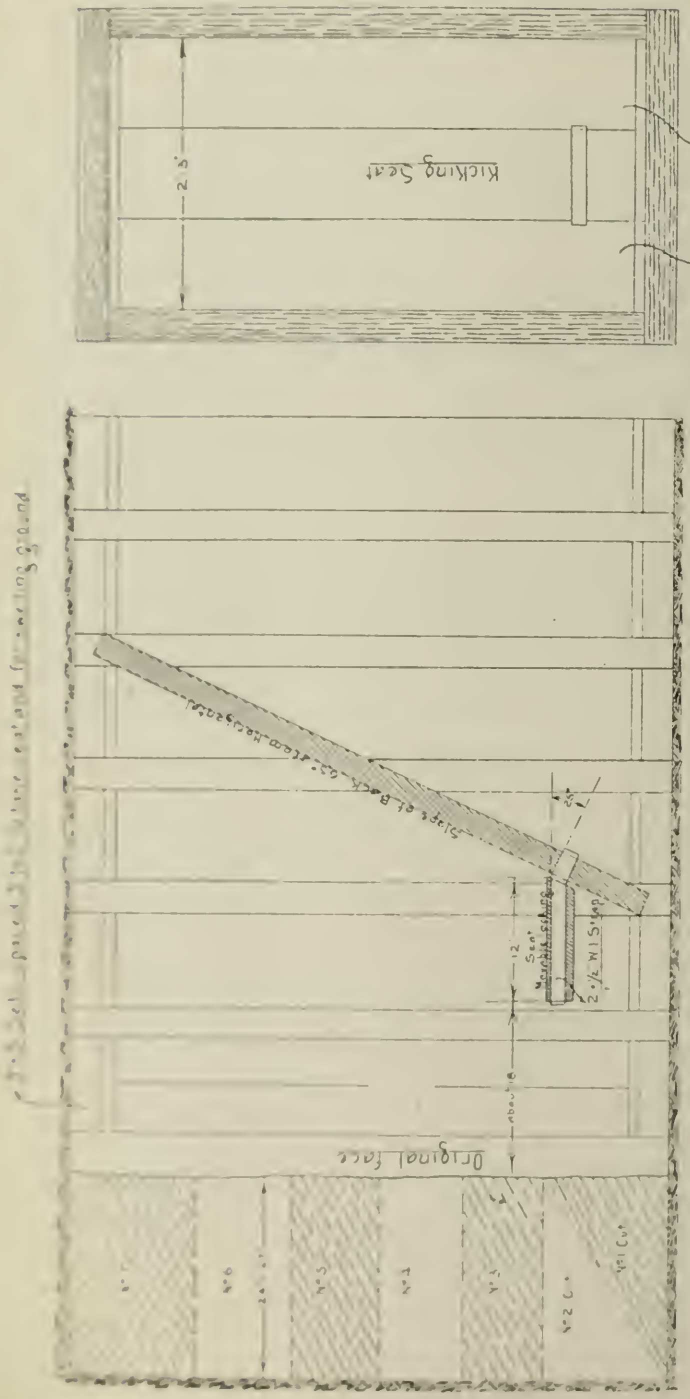


Fig. 4.
General Arrangement Clay-Kicking Seat.

being seated on a movable seat and using the handle of the spade as a lever with which to break down the face. Fig. 4 gives a diagrammatic sketch of the operation.

A sliding seat fixed to sloping back is set in the centre of the gallery. This seat is so arranged that it locks automatically at any position. The operator adjusts the seat to his liking, and then, with both feet straddling the spade, undercuts the face for about 2 ft. to 2 ft. 3 in. This operation completed, he takes cuts off the face from the undercut to the roof of the gallery, still using the spade and prying down the slice with the aid of the spade-handle. Throughout the operation the seat is adjusted to suit the varying height. The spoil is removed from both sides of the kicking seat without interfering with the operation of the kicker.

With a sharp-edged spade the whole operation is wonderfully silent and the progress remarkable. The following figures illustrate the progress which can be made. The galleries in these cases are the standard mine gallery, 4 ft. 3 in. by 2 ft. 3 in. in the clear, 3-in. space between sets.

No. 1.—Clay-kicking Competition, Second Army Mine School.

Conditions.—Team, 4 men; shift, 4 hours; ground, medium-hard blue clay. Points awarded for speed and silence; latter judged by listening party in an adjacent gallery.

Team No.	Sets timber erected.	Progress.	
		ft.	in.
1	9	7	7
2	8	6	10
3	8	6	9
4	8	6	9
5	7	6	8
6	8	6	7
7	8	6	6
8	7	6	5
9	7	5	10
10	6	5	6
11	6	4	11

No. 2.—These footages were obtained under actual mining conditions. Sets spaced 5 in.; 4 face-men; 8 fatigues for bagging spoils; 6-hour shifts; ground, ideal blue clay.

		Progress.	
		ft.	in.
No. 2.—	April 24	26	3
	,, 25	25	3
	,, 26	27	8
	,, 27	27	3
	,, 28	21	5
	,, 29	27	3
	,, 30	28	9
	May 1	23	10
	,, 2	25	7
	,, 3	30	7

With clay-kicking the average weekly progress in a standard mine gallery was about 70 ft.

(*b*) Dugout Construction and Main Infantry Subways.—The galleries in this case were 6 ft. 3 in. x 3 ft. 6 in. in the clear; timber stood close together; ground, clayey sand, fairly dry; shift consisted of 2 face-men, 3 shovellers, and 7 infantry fatigues, working 6-hour shifts. Method of excavation, pick and shovel.

Figures for a week's progress:—

	Progress.	
	ft.	in.
May 22	20	0
,, 23	20	4
,, 24	33	2
,, 25	36	2
,, 26	40	0
,, 27	20	4
,, 28	42	0

The low footages of 22nd, 23rd, and 27th May were due to long interruptions for "Stand to" on those days.

SHAFT SINKING.

Shaft sinking was confined to—

(1) Sinking with steel cylinders through the water-bearing strata, and continuing with framed sets in the dry clay.

(2) Sinking with crib timber through the surface strata.
(3) Underlie shafts.

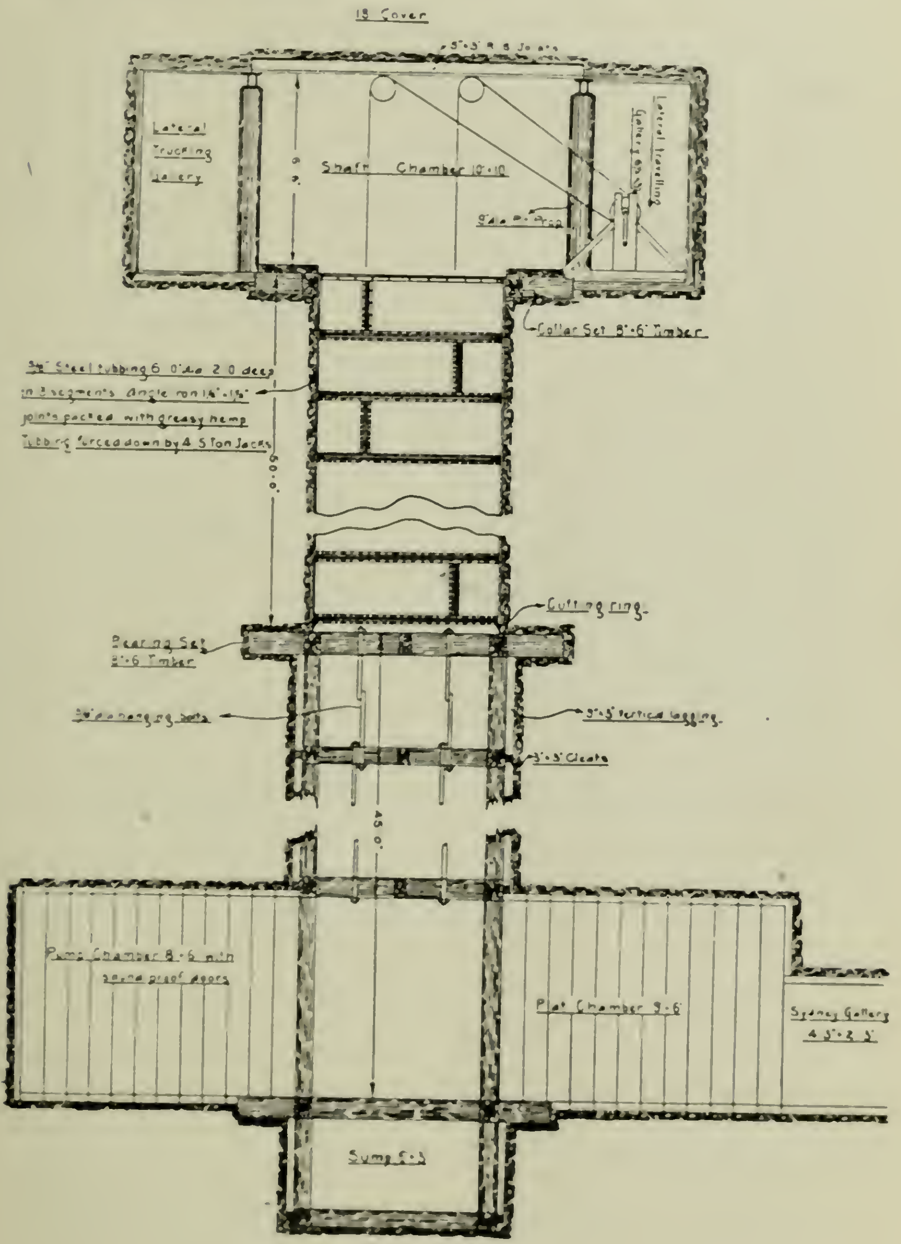

15 Cover
5"·5" R S Joists
Lateral Trucking Gallery
6' 9"
Shaft Chamber 10·10
9"·9" Prop
Lateral travelling Gallery 6·3
Collar Set 8"·6" Timber
3/8" Steel tubbing 6' 0" dia 2' 0" deep
in 3 segments Angle iron 1½"·1½"
joints packed with greasy hemp
Tubbing forced down by 4 5 Ton Jacks
60' 0"
Cutting ring.
Bearing Set 8"·6 Timber
Steel hanging bolts
9"·5" vertical lagging.
3"·3" Cleats
45' 0"
Pump Chamber 8·6 with sound proof doors
Plat Chamber 9·6
Sydney Gallery 4' 5"·2' 5"
Sump 5·5

FIG. 5.
DETAILS "SYDNEY" SHAFT.
Scale—⅛ in. = 1 ft.

(4) Stepped incline shafts for dugouts and machine-gun emplacements.

(1) Figs. 5 and 5A give details of the Sydney shaft sunk on Hill 60 by this company.

A shaft chamber with 18 ft. of head cover was excavated. The dimensions were 10 ft. square and 6 ft. 6 in. high. The roof was reinforced with 5 in. x 3 in. rolled-steel joists for safety, as well as to supply a solid base for four 5-ton lifting-jacks, which were employed to drive the steel cylinders down. A rectangular collar set was placed in position, and the rest of the floor of the shaft chamber securely floored. The steel tubbing was 6 ft. in diam. and in three segments; details are shown in sketch.

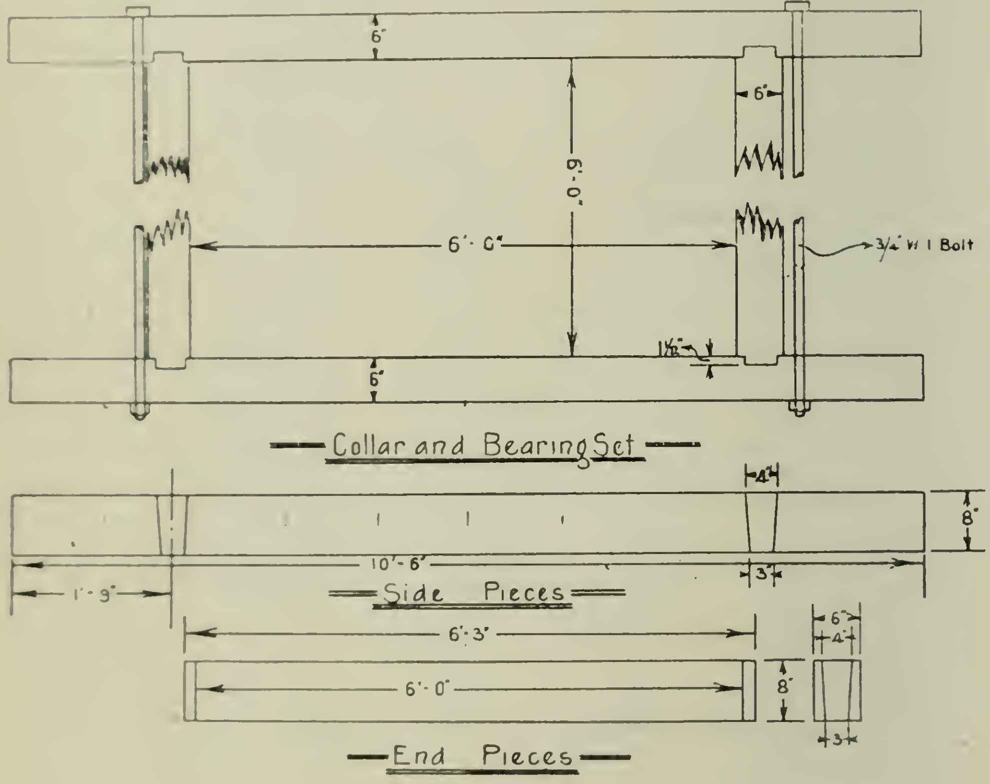


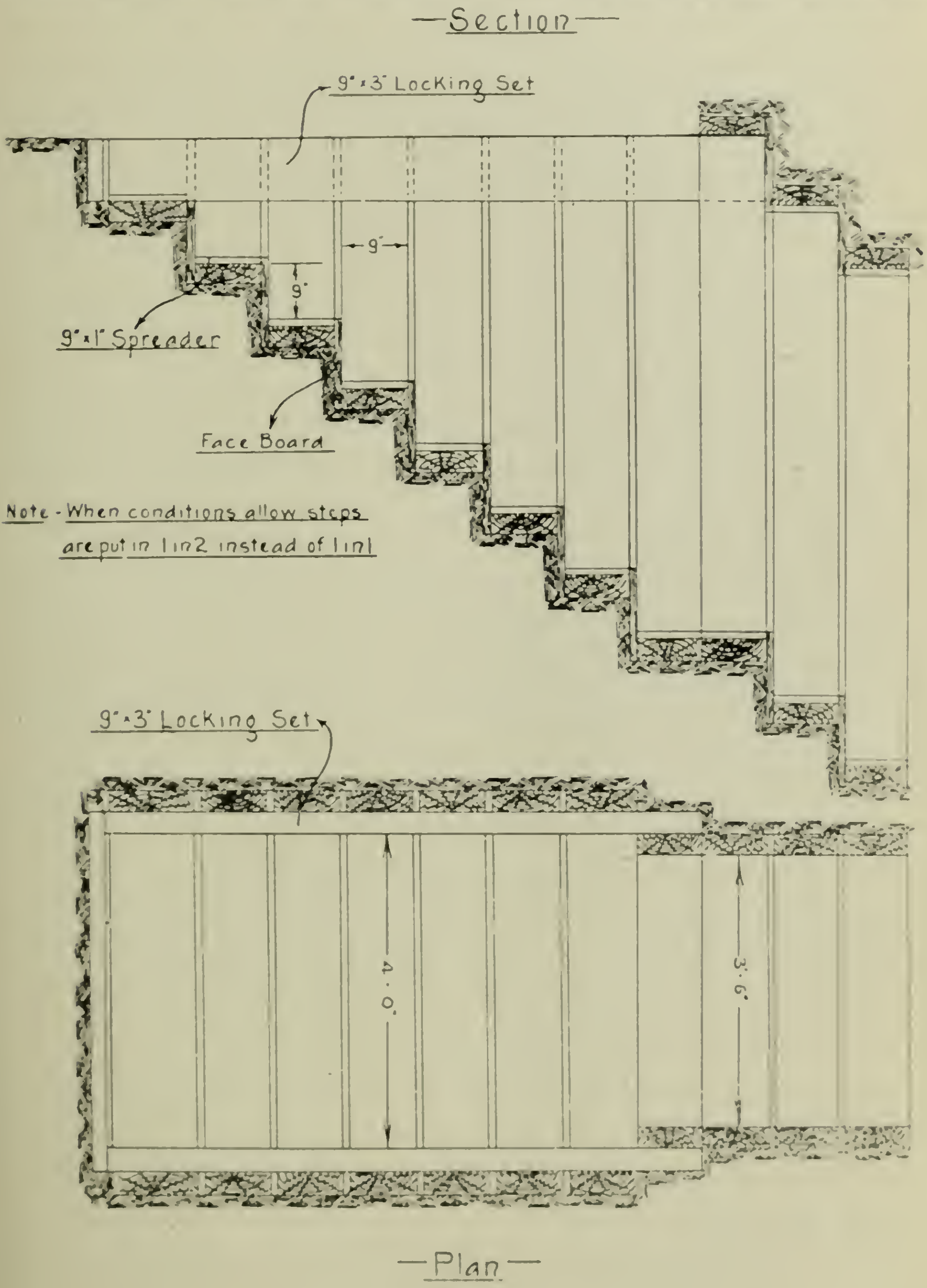
FIG. 5A.

DETAILS "SYDNEY" SHAFT.

Scale—⅜ in. = 1 ft.

A cutting ring was placed on the first ring and the ground excavated, and the ring cased as it was driven down. After passing the running-sand strata and reaching a depth of 10 ft.

below in solid blue clay the steel tubbing was dispensed with and frame sets used to complete the shaft.



Note - When conditions allow steps are put in 1 in 2 instead of 1 in 1

Fig. 6.
Stepped Dugout Entrance.

(2) The following figures are of interest, showing progress in this method.

Data.—Dimensions of shaft, 6 ft. x 3 ft. in clear.
No. of men per shift, 6.
Hours worked, 6 hours on and 6 off.

Date.		Progress. ft.	in.
Nov. 4	..	8	0
,, 5	..	11	6
,, 6	..	10	9
,, 7	..	7	9
,, 8	..	4	0

Total, 42 ft.
Progress, 3.7 in. per hour.

Remarks.—Eight hours lost, due to enemy shelling. Progress included laying collar set, plat set at 36 ft., and boarding bottom of sump.

Nature of country—
15 ft. surface yellow clay (damp).
2 ft. water-bearing sand.
Balance blue clay (dry).

(3) Underlie shafts were used in mine systems and in dugouts. In the latter case steps were installed for travelling purposes.

The timber sets employed were 5 ft. high at right-angles to the dip and 3 ft. 6 in. wide.

This type of shaft presented no unusual features.

(4) Stepped incline shaft.—Fig. 6 shows details for this type of dugout entrance. It has the advantage of using standard subway sets and forms the travelling way at the same time.

MINE TIMBER.

It was early seen that the magnitude of the mining operations on the Western Front necessitated the standardization of mine timbers. All timber employed in mining operations was Oregon pine, and of size 9 in. x 3 in.

Three standard sets were employed, and Fig. 7 gives the type of construction used—

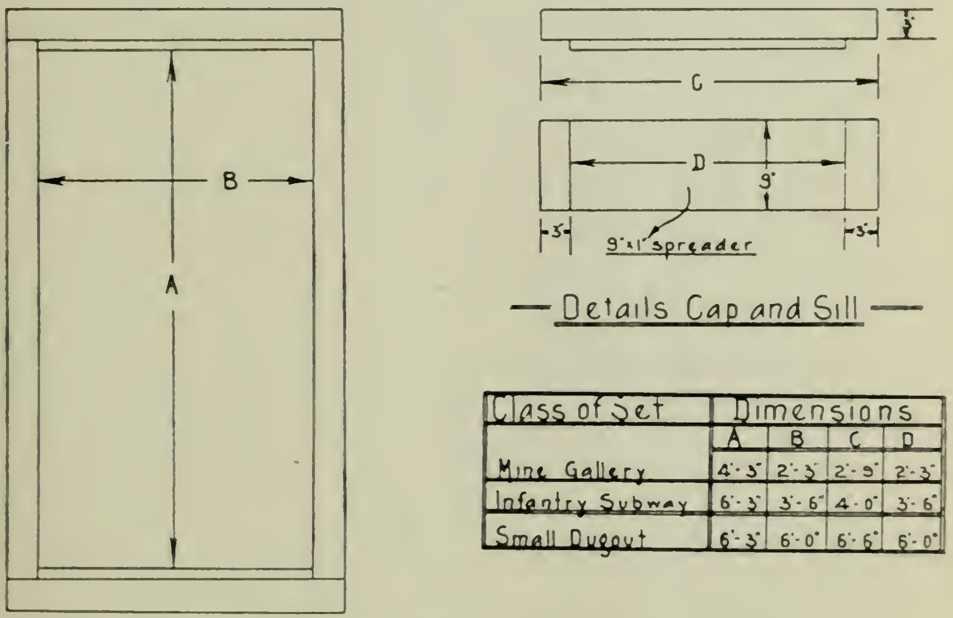
(1) Standard mine gallery set; dimensions, 4 ft. 3 in. x 2 ft. 3 in. clear.

(2) Standard infantry subway set; dimensions, 6 ft. 3 in. x 3 ft. 6 in. clear.

(3) Standard small dugout set; 6 ft. 3 in. x 6 ft. in clear.

Special sets, such as those for shaft timbers, collar sets, etc., had to be ordered in advance from the Royal Engineers' park.

The quantity of timber used may be judged by the fact that the average progress of this company while at Hill 60 was approximately 300 ft. per week.



Class of Set	Dimensions			
	A	B	C	D
Mine Gallery	4'-3"	2'-3"	2'-9"	2'-3"
Infantry Subway	6'-3"	3'-6"	4'-0"	3'-6"
Small Dugout	6'-3"	6'-0"	6'-6"	6'-0"

Fig. 7.

Standard Mine Gallery Set.

Handling and Disposal of Spoil.

The dirt, when broken in the face, was shovelled into hempen bags about 2 ft. long and 10 in. wide and the neck closely tied. In general the tactical situation did not permit of a truck being employed within about 100 ft. of the face, so for this distance the bags had to be man-handled. It was found by experience by our own listeners that slowly dragging the bags along the timbered floor was the quietest method of handling them, and from the face to the truck this system was employed.

Fig. 8 gives the leading dimensions of the truck and type of tracking employed.

This truck could take about 8 to 10 sand-bags.

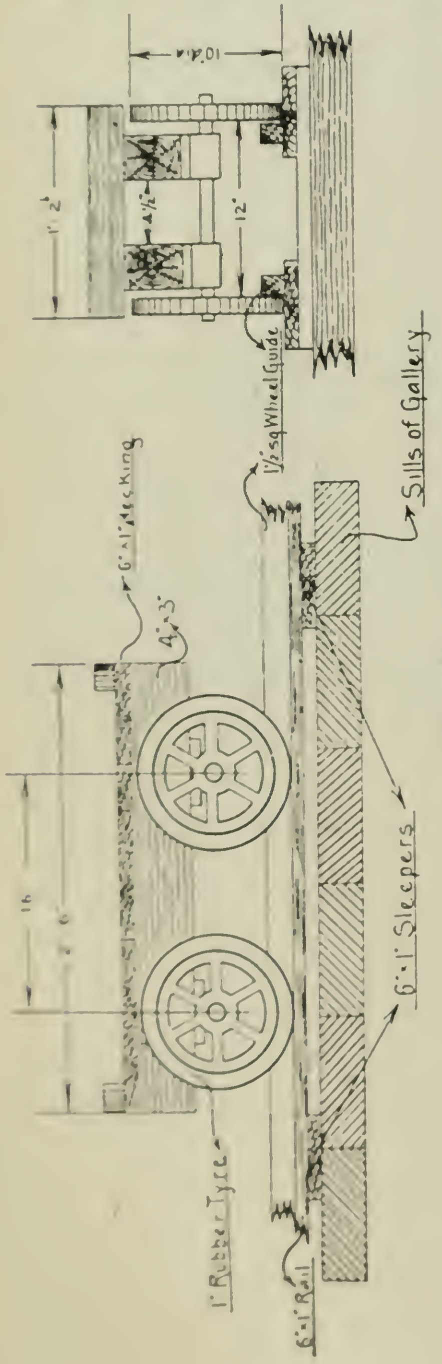


FIG. 8. MINE TRUCK AND TRACKING.

The tracking was very portable, being in 8-ft. lengths and readily laid.

In inclined shafts the truck was hauled direct to the surface. In vertical shafts the bags were put into a sling and hoisted on an ordinary windlass with an up and down rope.

Disposal of spoil was a vital consideration in maintaining the secrecy of the mining operations. The deeper workings being in blue clay, every care had to be exercised in the disposal of the spoil. It had the unfortunate property of discolouring the sandbags a dark blue colour, which rendered them highly visible to aircraft observation.

The presence of blue clay on the surface was a sure indication to either side of the existence of deep mining.

The spoil in sand-bags was used for revetting trenches, covering dugouts, etc., but the balance was dumped into the railway cutting, which afforded a secure dumping-ground.

VENTILATION AND DRAINAGE.

Small geared rotary fans were usually employed for ventilation. They were worked by two men, and were capable of supplying a strong current of air up to 300 ft. The delivery pipe was rubber hose 3 in. in diam., reinforced with wire-binding to keep it distended.

The gearing on these fans made them very noisy, and the sound carried distinctly along long lengths of gallery.

For more silent working and with equal efficiency 6-ft. blacksmith's bellows were employed. These were generally installed two in series, and gave a good flow of air with a minimum of noise.

For drainage the general service pump was chiefly employed in isolated positions or where the need of silence prevented the installation of power pumps. These pumps were two-stroke 3-in. diam. cylinders operated by two men, and were capable of a lift of about 80 ft., though not generally employed beyond 40 ft. of head. In a mine system such as Hill 60 the pumping absorbed a large number of men.

SURVEYING AND PLAN RECORDS.

All new work was brought up to date weekly by a theodolite survey. As all galleries were driven as direct as possible, to minimize the problem of disposal of spoil, the surveying was very elementary.

The mine system was kept accurately co-ordinated with the trench system, and as a result, with the aid of aeroplane photos. showing both the enemy's and our system, we were able to accurately co-ordinate our positions with the enemy trench system.

The plans were all plotted on the co-ordinate system. The daily progress was plotted, and at the end of each week slip tracings of all gallery progress were forwarded to the Controller of Mines.

A large-scale map showing the listening posts was kept at headquarters, and a daily tabulated sheet showing the listening reports from every post was made.

Direction of enemy progress was plotted from direction listening reports from carefully-checked stations.

CHARGES AND EFFECT OF MINES.

For calculating the charge and the probable effect of a mine certain empirical formulæ have been arrived at as the result of practical experience. These formulæ gave very accurate results in mining operations on the Western Front, and a digest of them is given.

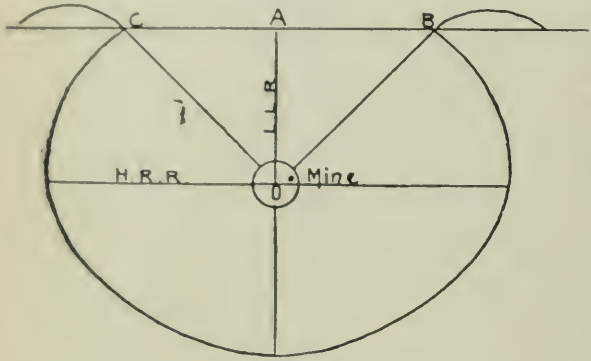


FIG. 9.
DIAGRAM ILLUSTRATING MINE DEFINITIONS.

Definitions (Fig. 9).—

(1) Mines are charges of explosives placed under the surface of the earth, the position and quantity of the charge depending on the object to be fulfilled—

(*a*) Whether it is desired to produce a crater at the surface which may be occupied by troops.

(*b*) or to damage the enemy's works above or below ground. In the latter case, where no crater is produced, the charge is known as a camouflet.

(2) The shortest distance from the centre of the charge to the surface of the ground—or, in the case of a camouflet, the shortest distance to the enemy's galleries—is known as the "line of least resistance" (L.L.R.), and is measured in feet. It is the line OA in plan.

(3) "Radius of crater" is the radius of the circular opening on the surface of the ground, and is the line AB on plan.

(4) Craters are classified in relation of diam. of crater to L.L.R.

Thus, in a one-lined crater BC = L.L.R.

" " two " " BC = 2 L.L.R.

(5) The distance from the charge to which the effect of the explosion is transmitted is called the "horizontal radius of rupture" (H.R.R.).

This is a vital consideration when—

(1) Estimating the destruction of enemy's works underground.

(2) Estimating the destruction of your own works underground.

Formulæ for calculating charges :—

If L = L.L.R.

r = radius of crater in ft.

c = powder charge in pounds.

s = variable, dependent on nature of soil,

Then in a common mine

$$c = S\ L^3$$

and the H.R.R. =

$$\frac{7}{4}\ \frac{10c}{s}$$

The values given to s are shown in the following table :—

Nature of soil.	Value of S.
Very light earth	0.80
Common earth	1.00
Hard sand	1.25
Clay mixed with loam	1.50
Blue clay, Hill 60..	1.60
Hard chalk	2.00

Crater Effects in Blue Clay.—These figures are the result of six mines fired in blue clay. The explosive was laid in kinked galleries, with the detonator inserted in 1-oz. gun-cotton primer surrounded by auxiliary detonators.

No. of Mine.	Charge ammonal in lbs.	Estimated L.L.R.	Dia. of crater in feet
1	31,000	60 ft.	180
2	15,000	45 ,,	150
3	13,500	42 ,,	140
4	12,000	42 ,,	140
5	1,800	30 ,,	70
6	600	16 ,,	46

These tests showed ammonal to be 3.6 times as effective as formula gunpowder. The above results, taking s to be 1.7, show the following efficiencies for ammonal in relation to *c* of the above formula.

No. 1	3.61
No. 2	4.23
No. 3	3.82
No. 4	4.30
No. 5	3.88
No. 6	3.14

Radius of Rupture for Ammonal in Clay.—The relationship between a given charge of ammonal and its radial rupturing effect must be determined when estimating—

(1) Distance within which

(*a*) enemy galleries or (*b*) our own galleries will be destroyed.

(2) Distance to be tamped for full efficiency of explosive.

The following equation has been deduced from over 100 mines to provide a simple estimation :—

For Clay.—

Charge of ammonal in lbs. = $(\text{H.R.R.})^3 \div 150$.

Transmission of Explosion.—The transmission of the explosion between neighbouring charges was a subject of experiment.

(*a*) The influence of a neighbouring blow upon detonators in a mine charge showed that in a No. 13 Mark IV. detonator the fulminate was more liable to explode than the bridge to fracture. Neither result should be experienced when the detonator is over 1/5 of H.R.R. from charge fired.

(*b*) The distance through which explosions can be transmitted between adjacent charges of ammonium nitrate explosives.

Three tests :—

No. 1.—50 lb. ammonal at about 1/5 H.R.R. from an initial charge of 50 lb. ; result—fired.

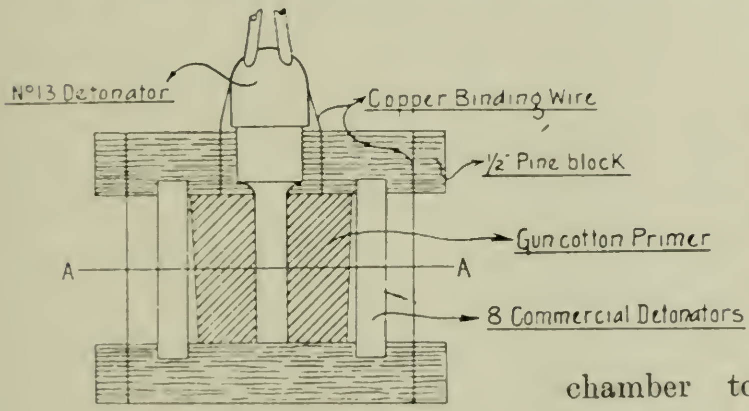
No. 2.—As above, but charge at $\frac{1}{2}$ H.R.R. ; result, nil.

No. 3.—Initial charge of 400 lb. with H.R.R. of 27 ft. at a distance of 5 ft. in solid chalk from a secondary charge of 1500 lb ; result—fired, producing a crater of diameter and depth equal to a charge of 1900 lb. ammonal.

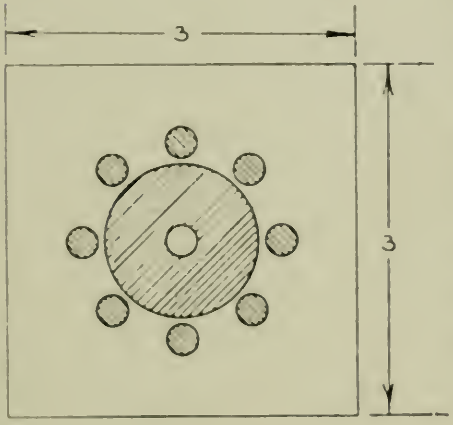
A further demonstration on mine of 84,000 lb. ammonal at a depth of 52 ft. in chalk, including overburden of 27 ft. of clay and sand, gave a crater 115 ft. in diam., showing ammonal to be 3.75 times as powerful as formula gunpowder.

CHARGING AND FIRING OF MINES.

The standard mine gallery set was 4 ft. 3 in. by 2 ft. 3 in. inside of timber. Consequently, for any charge of explosive over 1000 lb., it was generally advisable to construct a chamber to receive the charge.



— Sectional Elevation —



— Section A A. —

FIG. 10.
ARRANGEMENT OF DETONATOR.

This could be accomplished for the average camouflet in the standard gallery by making a T head at the end of the gallery. In the large mines the standard gallery was enlarged to a 6 ft. 3 in. by 3 ft. 6 in. in the clear, and sufficient galleries of similar size were put in at right-angles to this new enlarged gallery to contain the charge. The only guiding factor in the design of charge chambers was to keep the charge as concentrated as possible.

The detonators used were Electric No. 13 Mark III., containing 43 grains of fulminate of mercury. The detonator was placed in a 1-oz. dry gun-cotton primer.

On top and bottom of the primer was placed a wooden cover, as shown in Fig. 10. These were recessed to take eight commercial detonators, which then surrounded the gun-cotton primer. The whole was then bound together with fine wire. The detonator, thus reinforced with the gun-cotton primer and eight commercial detonators, was placed in a 50-lb. box of gun-cotton, forming the main primer.

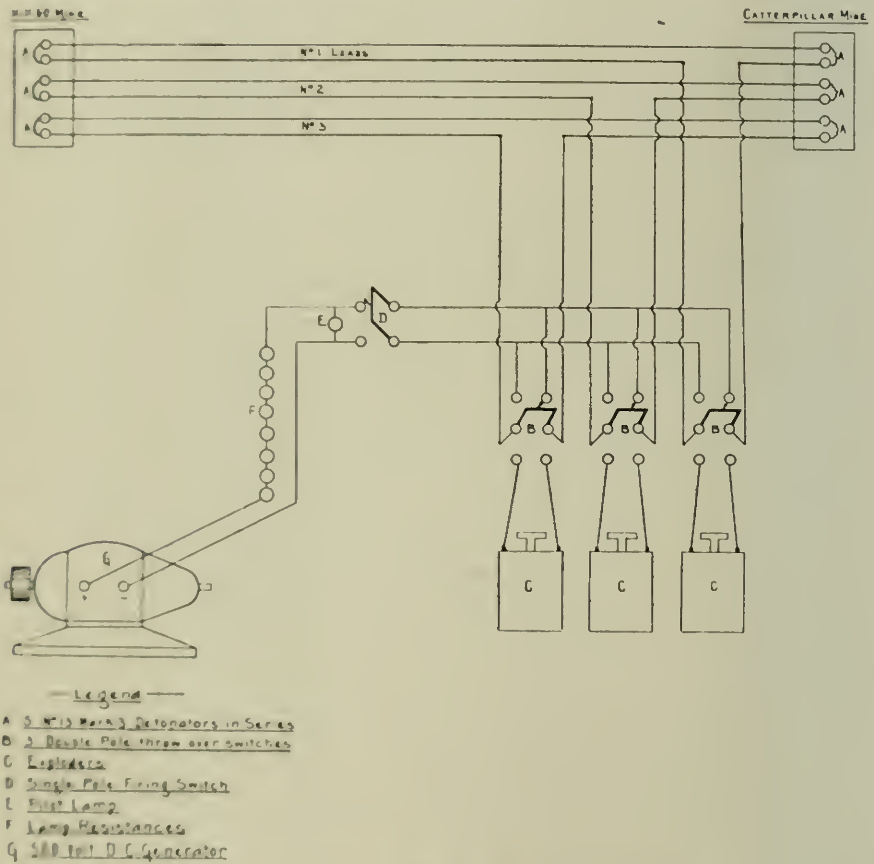


Fig. 11.
Firing Connections—Hill 60 Mines.

In each of the large mines there were three circuits with five No. 13 Mark III. detonators in series. Two of the circuits had armoured quod cable, while the third circuit had E.I. Mark II.

cable. This had six strands of copper and one of steel, covered with vulcanized india-rubber.

Table No. 1 gives all the details of the firing circuits in each mine. The leads were brought to a central terminal testing station. Here each set of leads was attached to brass terminals mounted on a well-insulated board.

There were two methods of firing—

(1) The exploder.

(2) Power from a D.C. 500-volt lighting set.

The mines were eventually fired by the current from the lighting dynamo, but in case of a breakdown to that set at the last moment three double throw-over switches and one control switch were placed in the circuit. Connected to the three double throw-over switches were three exploders. Fig. 11 shows a diagrammatic view of the connections.

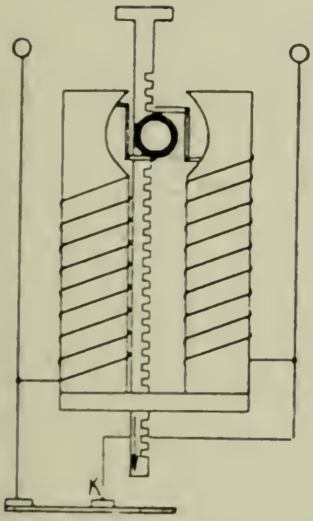


Fig. 12.
Diagram of Exploder Connections.

The service exploder consists essentially of a small series-wound dynamo. The fired magnets and armature are wound with insulated wire. The armature is provided with a two-part commutator and caused to revolve by means of a rack and pinion. It is provided with a free wheel so that the armature is only rotated on the down stroke.

Fig. 12 shows diagram of connections.

There is always some residual magnetism in the field magnets, and the armature revolving on the downward stroke of the handle generates a current. The maximum E.M.F. is developed at the bottom of stroke.

The contact at K is now broken by the end of the rack depressing the spring, and the current flows through the external circuit. The personal factor enters largely into the use of the exploder. The rack must be made to descend as swiftly and smoothly as possible.

TABLE No. 1.

	Number of detonators No. 13, Mark III.	Resistance of detonator, cold, in ohms.	Total resistance in ohms of detonators, cold.	Resistance of detonator at fusing point.	Total resistance of detonators at fusion in ohms.	Length of armoured quod cable in feet.	Resistance of quod cable per 100 ft. in ohms.	Total resistance of quod cable in ohms.	Length of E.I. Mark II. cable in feet.	Resistance of E.I. Mark II. cable per 100 ft. in ohms.	Total resistance of E.I. Mark II. cable in ohms.	Theoretical resistance of circuit cold in ohms.	Practical resistance of circuit in ohms by Wheatstone bridge test.	Total resistance of circuit at fusion point.
HILL 60 MINE.—														
No. 1 circuit	5	1.05	6.25	2.6	13.0	1320	.204	2.70	500	.44	2.20	11.15	11.00	17.9
No. 3 circuit	5	1.05	6.25	2.6	13.0	nil.	nil.	nil.	1820	.44	8.00	14.25	14.10	21.0
CATERPILLAR MINE.—														
No. 1 circuit	5	1.05	6.25	2.6	13.0	1760	.204	3.59	400	.44	1.76	11.60	11.30	18.36
No. 3 circuit	5	1.05	6.25	2.6	13.0	nil.	nil.	nil.	2160	.44	9.50	15.75	16.00	22.5

NOTE.—No. 2 set of leads in each mine similar to No. 1 set of leads respectively, and so is not included.

DETAILS OF FIRING ARRANGEMENTS, HILL 60 MINES.

Fig. 11 shows a diagrammatic arrangement of wiring. It will be noticed that the Hill 60 and The Caterpillar mines were fired in series, and the three sets of leads connected to the dynamo circuit in parallel.

The single-pole firing switch D was left open while the three double-pole throw-over switches B were closed on dynamo circuit.

To the other terminals of these switches were connected the three exploders.

A pilot lamp, E, was installed to indicate that all was correct with the dynamo at the firing station.

Lamp resistances were inserted in the circuit to prevent a flash-over at the generator when the firing switch D was closed.

This arrangement allowed the exploders to be used should any failure of the dynamo be met with at the last moment.

An earth was connected to the sparking-plug of the oil engine and dropped when the mines were fired in case the eruption may have damaged this installation.

EXPLOSIVES AND DETONATORS USED.

The explosives used were all high explosives of the shattering type. Only two classes were employed—(1) ammonal and (2) gun-cotton.

(1) Ammonal for general use in military mining was a product of this war. Its composition is as under :—

	%
Ammonium nitrate ..	65
Trotyl (T.N.T.)	15
Coarse Aluminium ..	16
Fine ,, ..	1
Charcoal	3

From tests described under "Charges and Crater Effects of Mines," it shows a strength about 3.75 times greater than formula gunpowder. It was packed in tins containing 50 lb., enclosed in a pine case.

(2) Gun-cotton was supplied in the form of wet slabs and dry primers. The following are the details :—

Slabs.—Weight, 15 oz. ; length, 6 in. ; breadth, 3 in. ; thickness, 1¾ in. ; remarks—with one perforation for primer.

Primer. — Weight, 1 oz. ; diameter, 1.35 in. top, 1.25 in. bottom ; height, 1¼ in. ; remarks—conical, with one perforation for detonator.

Detonators.—As all charges were fired electrically, only one type of detonator was used—*i.e.*, No. 13 detonator, Mark III. Fig. 13 shows its construction.

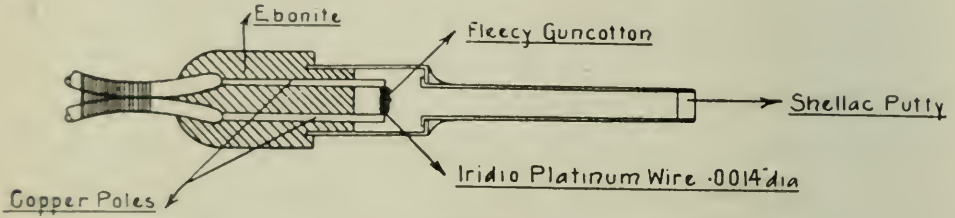


FIG. 13.

CONSTRUCTION NO. 13, DETONATOR MARK III.

The attached table gives detailed particulars :—

Material of bridge wire	iridio-platinum
Weight of bridge wire per yd.	.45 gr.
Length	.25 in.
Diameter	.0014 in.
Resistance cold at 60° F.	1.05 ohm.
,, when just hot enough to start ignitor	1.30 ohm.
,, at fusing point	2.6 ohm.
Smallest current that can fire	.35 amp.
,, ,, ,, ,, fuse	.8 amp.
Smallest current to be calculated for to fire charge	.8 amp.
Largest safe testing current when testing charges	.05 amp.

DETAILS OF CHARGES AND CRATER EFFECTS.

HILL 60 MINES.

(1) Mine under Hill 60—

Charge—ammonal, 45,700 lb. ; gun-cotton, 7800 lb. ; total, 53,500 lb.

Depth from surface, 90 ft., equals L.L.R.

Soil factor, 1.6.

Theoretical radius of crater from charge formulæ, 105 ft.

Diameter, 210 ft. = 70 yd.

Actual diameter by measurement = 68 yd.

Depth of crater after debris had settled = 33 ft. from original ground-level. The rim around crater stood about 10 ft. above this.

Radius of rupture to complete obliteration = 140 ft.

Length of 4 ft. 3 in. by 2 ft. 3 in. gallery tamped = 240 ft.

(2) Mine under The Caterpillar—

Charge—ammonal, 70,000 lb.; total, 70,000 lb.

Depth from surface, 100 ft., equals L.L.R.

Soil factor, 1.2.

Theoretical radius of crater from charge formulæ = 135 ft.

Diameter of crater, 270 ft. = 90 yd.

Actual diameter by measurement, 273 ft. = 91 yd.

Depth of crater after debris had settled = 51 ft. from original ground-level. The rim around the crater stood about 15 ft. above this.

Radius of rupture to complete obliteration = 190 ft.

Length of gallery (4 ft. 3 in. x 2 ft. 3 in.) tamped = 510 ft.

The mines were fired at 3.10 a.m. (summer time) on 7th June, 1917.

It was found that the amount of tamping put in with both charges well ensured the L.L.R. being to the surface. The mine system was left practically intact from about 100 ft. from the face of the tamping.

A point of interest is the close agreement of the calculated and actual dimensions of the craters formed.

ELECTRICAL TESTING AND INSTRUMENTS EMPLOYED.

As before mentioned, all mines and camouflets were fired electrically. In the large mines the electrical condition of the leads was a vital question, and in order to be well posted as to their condition two series of tests were made—

(1) For continuity, taken once every 6 hours; (2) for resistance, taken once every day. The testing set supplied to tunnelling units contained a set of resistance coils, to 100 ohm; a three-coil galvanometer; one dry electric cell; two reels iridio-platinum wire, .0014 in. diam., the same as the bridge wire of electric detonators.

Resistance coils are arranged as in Fig. 14, so as to be as easily connected up as a Wheatstone bridge. They are graduated from 1/20 ohm to 100 ohm, and are also furnished with clips ¼ in. apart for holding the iridio-platinum wire used in the fusion test.

It will be noted that the key is placed in the battery circuit, and that the galvanometer is always in circuit.

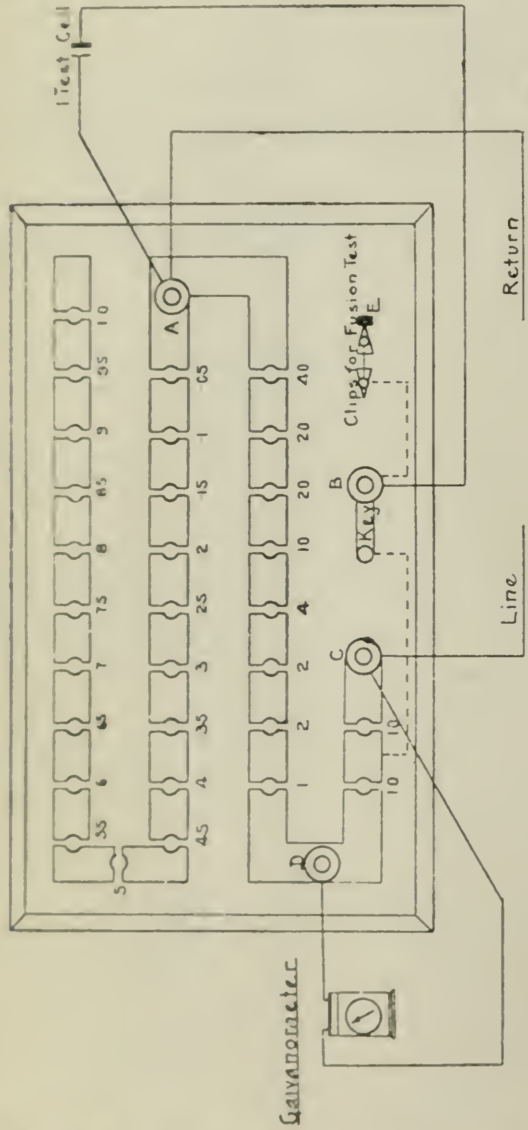


FIG. 14.

100 OHM. RESISTANCE COILS SHOWING CONNECTIONS FOR TESTING RESISTANCE OF LINE FUSES, ETC.

NOTE.—When testing Exploder it is placed in series between A and Terminal of Fusion Clips E. Between these clips is placed ¼-in. Standard Iridio-Platinum wire; the Key and C are short-circuited and the two ohm plugs kept in. Galvanometer and cell are disconnected.

The three-coil galvanometer has three coils, the bottom of which are wound to 2, 10, and 1000 ohm respectively, any of which can be brought into circuit by a brass plug. The end of all the coils is connected to one terminal, the others being connected each to its respective brass block.

Fig. 15 shows diagram of connections.

The 1000 ohm coil is used for comparing and indicating small currents up to .005 amp. The 10 ohm coil is used with the Wheatstone bridge. The 2 ohm coil is used for continuity testing.

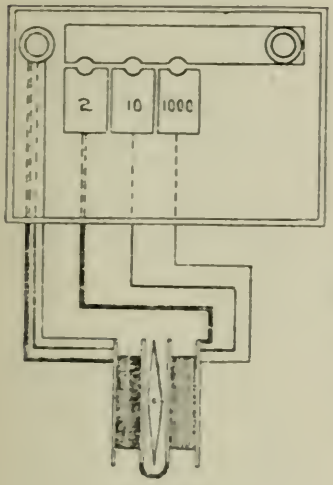


FIG. 15.
GALVANOMETER.

The dry electric cell is a special form of dry cell provided with a resistance coil that brings the total internal resistance up to 12 ohm. This obviates the possibility of anything but a very small current being sent out by it under any circumstances; its E.M.F. is 1.5 volts.

Fig. 16 shows connections.

The electrical testing may be divided into—(1) testing the firing apparatus, (2) testing the detonators, (3) testing the conducting wires, (4) testing the complete circuit after everything is ready for firing.

(1) *Testing Exploders* is carried out with the firing resistance coils connected up as in Fig. 14. The key is cut out by a short lead as shown.

If in good condition the Mark V. exploder should fuse standard iridio-platinum wire through 100 ohm. The exploder should not be tested with a resistance it is unable to fuse through, but should be tried gradually until the machine fails to fuse.

To be safe, the exploder must be capable of fusing through a resistance 25 % greater than the calculated resistance of the circuit at fusing point.

(2) *Testing Detonators.*—All fuses and detonators should be balanced by the Wheatstone bridge method. The connections are made as in Fig. 14. The two 10-plugs are removed, and, with all other plugs in, depress the key and observe the direction of the throw of the needle. This gives the resistance when too low. Now unplug sufficient resistance to give a throw to the

needle in the opposite direction. This resistance is too high, and the correct resistance should be taken as a mean of the resistances which give indications on the galvanometer as being just too high and just too low.

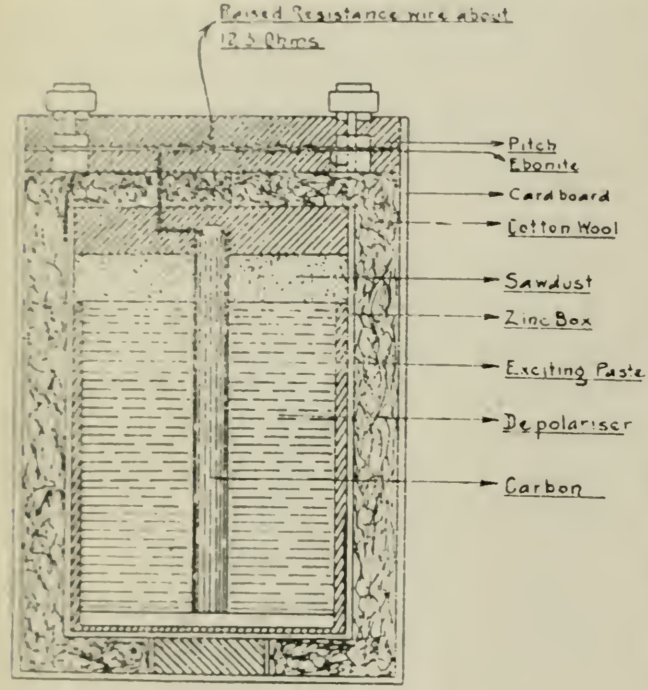


Fig. 16.
Test Cell.

Test of Detonators for Over-Sensitiveness—Detonators should not fire in 4 seconds with a current of .32 amp.

Test of Detonators for Under-Sensitiveness.—A few detonaators from each box should be fired with .45 amp. If they fail to fire in 4 seconds the whole box should be rejected.

(3) *Testing Conducting Wires.*—The continuity test is made with a galvanometer and battery in the circuit.

Resistance tests are made on the Wheatstone bridge.

(4) *Testing Complete Circuit.*—When the mines are laid, the theoretical resistance (cold) of the detonators and cable can be estimated from data supplied with each article. The whole circuit should then be balanced with the test cell by the method of the Wheatstone bridge. If the actual resistance agrees within small limits with the theoretical the circuit can be taken as correct.

Example (Fig. 17):—

	ohm.
7 detonators	7.05
Main leads	4.00
Branch leads	2.00
Leads between charges	1.00
Total theoretical resistance ..	14.35

If resistance measured from A is, say, 18 ohm, there is a bad joint. If infinite, there is disconnection. If considerably less there is a leakage. If a steady reading is difficult to obtain there is probably a loose connection.

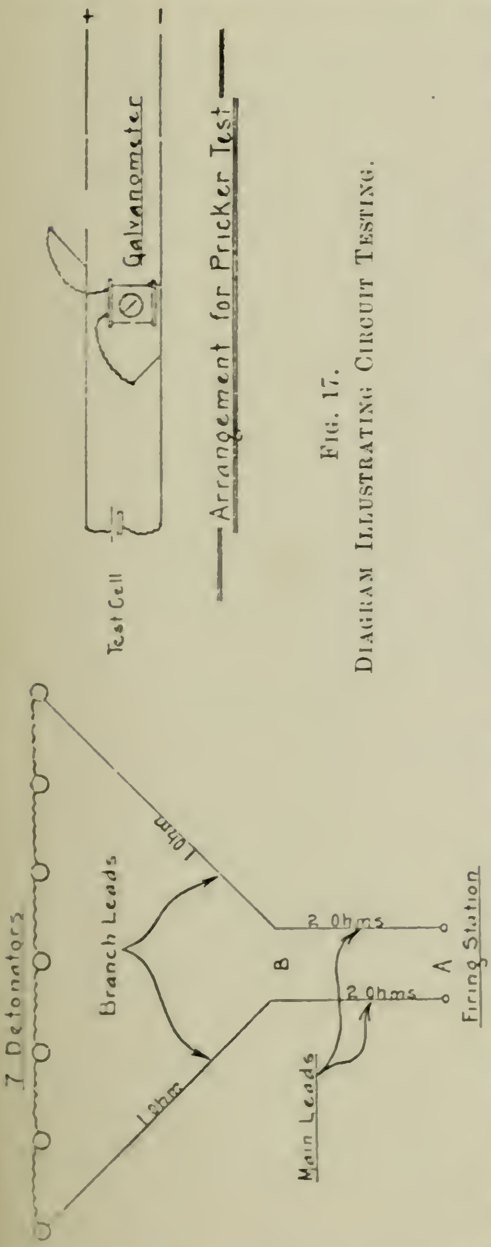


Fig. 17.

Diagram Illustrating Circuit Testing.

These faults can be generally readily localized by what is known as the "pricker test," which consists of attaching two needles to flexible leads of the galvanometer and making the cross connections by piercing the insulation.

Arrangement of test is shown in Fig. 17.

Mine Listening and Instruments Employed.

It can justly be claimed that, in common with the other branches of modern warfare, mine listening developed along very scientific lines. The advance from the stage of listening with the unaided ear to the use of the most highly specialized instruments was rapid. Yet the general public and journalists seem to have been unaware of this fact. As late as May, 1916, it was common to find illustrated papers depicting the tunneller listening for enemy mining with his ear upon a duck-board or in a stooping attitude with hand over his ear, the better to concentrate the supposed noises. Had such been the true case, the tunneller's lot would have indeed been an "uplifting" one.

However, we were aided by instruments of the most delicate nature, chief of which were the geophone and various types of microphones with electrical connections. The latter enabled listening to be carried out at a great distance from the actual listening post, and also lent itself to the establishment of central listening stations.

The geophone (Fig. 18) was in general application, as it possessed the double advantage of (1) giving a true reproduction of sound, and (2) giving a true determination of direction.

In construction it consisted of a mass of mercury enclosed on either side by a mica diaphragm and surrounded by an annular block of wood. Over the mica diaphragm on top and bottom are placed wooden covers, with an air space about ⅛-in. deep, and the size of the mica diaphragm. Connected to this air-space are two tubes, to which are attached a double stethoscopic ear-piece to convey the sound to the ears. Fig. 18 gives the construction in detail.

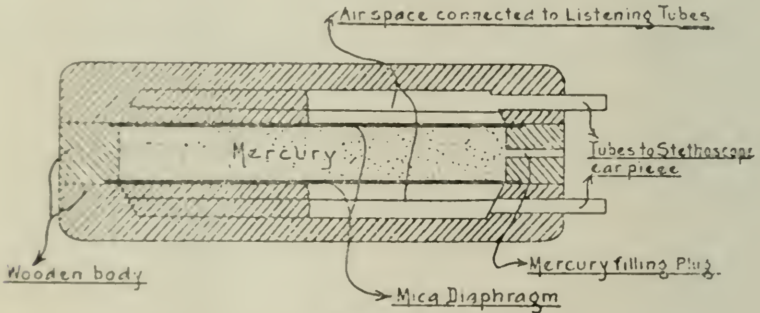

Air space connected to Listening Tubes
Mercury
Tubes to Stethoscopic ear piece
Wooden body
Mercury filling Plug
Mica Diaphragm

FIG. 18.
DIAGRAMMATIC SECTION OF GEOPHONE.

Geophones are issued in pairs with a compass mounted on a piece of deal board about 9 in. long, pointed at both ends, to allow finer adjustment to the centres of geophones when these are used in pairs for determining direction.

For magnification of sound only a single geophone is used. At each listening post the listener, when only observing for sounds of enemy mining, uses the single geophone arranged as shown in previous sketch. The geophone is placed on a bench cut in the clay, and the listener, being comfortably seated, adjusts the ear-piece to his ear, and then, with watch and log-book, correlates the sounds heard and describes in detail what he considers to be their nature. It is essential that silence be observed, that the rubber ear-piece tubes hang freely and do not brush against each other, and that all equipment of the soldier be free from the liability of producing creaking sound.

The double geophone is used for determination of direction. The two geophones, previously calibrated, are used in this case, one rubber tube of the stethoscope ear-piece being attached to each geophone. The unused nipple on each geophone is plugged with a rubber stopper. In principle the two geophones now act as highly sensitive ears, and, of course, it follows that the listener himself must possess unimpaired hearing.

As with the natural ear, the direction of sound is arrived at by a wave length striking one ear quicker than the other, whence we get the impression that the sound is to the right or to the left. When the wave length meets both ears simultaneously we get the impression that the sound is directly ahead or behind. The same principle applies to the use of the double geophone.

To be a successful listener one must possess the faculty of discarding all preconceived ideas as to the direction from which the sound comes.

The two geophones are placed on a bench cut in the clay and detailed conditions apply as before mentioned. Let us assume that the sound is from the right. The right-hand geophone will record the noise more strongly, and so the left-hand geophone, or both, are slowly operated until the observer unconsciously notes that the sound is directly ahead. The compass is then placed across the centre of the geophones and the magnetic reading noted. This is again re-checked as often as desired. For determining the elevation of the sound the same principle is applied, but in this case the geophones are placed along the wall on the clay one above the other, and the angle of dip or elevation noted.

The following table (No. 2) will serve to illustrate clearly the sensitiveness of the geophone. These tests were carried out in blue clay similar to conditions on Hill 60.

TABLE NO. 2.

Nature of sound.	Distance from source.	With unaided ears.	With geophones.
Light picking	175 ft.	Just distinguished	Clearly heard
Clay-kicking	125 ,,	Sounds of working not heard	All sounds distinguished
Shovelling on timber floor	110 ,,	Just detected by expert listener	Clearly recognized
Clay falling from face	60 ,,	Occasionally heard	Distinctly heard
Falling clay; filling bags walking in boots	45 ,,	Heard, but not usually recognized	All sounds clearly distinguished
As above	40 ,,	Recognized	Very distinctly heard
Walking in muffled boots and general gallery sounds	30 ,,	Just recognized	Distinctly heard all sounds of
Walking in muffled boots and trolleying with rubber-flanged trolley wheels	20 ,,	Clearly recognized	Gallery work distinguished very readily from this distance
Talking and clothes brushing against gallery	10 ,,	Just heard	
Talking and bag-dragging	5 ,,	Heard quite plainly.	

Electrically-connected Microphones.—The only instrument of this class with which the writer has had personal experience is the "western electric mining detector." It consists, briefly, of a microphone connected electrically with a telephone ear-piece, so that earth vibrations are transformed into electrical impulses. In the circuit is a set of five variable resistance coils, which enable the electric impulse to be reduced to zero. The instrument is calibrated by placing the microphone in the same nature of soil as that in which it is intended to be used. Then at regular intervals of, say, 5, 10, 15, 20, 25 ft., and so on, a constant bumping on the ground is made. The person calibrating the instrument now places a resistance in the circuit until the sound can be just heard. This point, of course, need only depend on the personal factor of the observer.

When all the distances have been calibrated we get two factors —(1) distance of sound from microphone, (2) resistance placed in circuit. From these a graph can be derived.

In actual work the sound at an unknown distance is heard: the resistance can be calculated, and from the graph the distance of the source of the noise found.

This type lends itself to the establishment of central listening stations, and it is thereby claimed to save labour in listeners. From the experience of No. 1 company this practice possesses many disadvantages when compared with the system of having a listener in every post using the geophone.

Take the case of the two systems side by side. Assume 50 listening posts.

With the geophone for every minute of the day there is at least one and perhaps three or four listeners capable of picking up any sound made during that period. Now for the listener on the central listening station. Considerable time must elapse before he can plug and unplug connections for the 50 posts and give a reasonable time to listening to each post. Consequently, all sorts of things may happen at the other extreme posts, and vital information may be lost. Again, he does not get such a clear reproduction of sound as does the man with the geophone.

It may be argued that a patrol with a geophone can investigate posts from which noises are reported from the central listening station, but against this procedure can be laid the following general conditions :—

In all mining systems a stage is eventually reached when both sides are fully aware that the other is mining against him. Consequently, it is only correct to assume that both sides strictly enforce silence in their operations, and it may from experience be almost given as a rule that either side only obtains vital information from the carelessness of the other. Consequently, with a geophone at each post these slips on the part of the enemy are noted, and a very true idea as to their nature instantly obtained. With the central listening station the post may have been recently disconnected, and very valuable information lost.

Training of Listeners.—All listeners were trained at the Second Army Mine School at Proven under the command of Capt. Pollock (of Sydney University). Here a model mine was made, with one gallery in the surface clay and the other in the blue clay. Adjacent to this, and entirely separated, was a second mine running at an angle to the first system.

In system No. 1 the men being trained for listening were posted from time to time at different listening posts, so arranged in conjunction with system No. 2 that the distance from the source of noises could be regulated.

In system No. 2 mining was carried out by a party of miners under conditions similar to front line work.

In the early stages of training the listener was given a schedule which showed the nature of the work being carried out in No. 2 system, thereby being enabled to associate the noises with their correct origin.

Later, he had to construct a schedule himself from his listening record, noting the time at which the varied operations of mining in No. 2 system were carried out and identifying each class.

Still later he was trained in direction of sound by the double geophone.

The course lasted ten days.

The lot of the listener is a most unenviable one, and, unfortunately, as regards the general public and perhaps the other arms of the service, is not truly recognized. It was a branch of duty which entailed constant faithful service without the glamour attaching to the other branches of the service. A listener might be posted hundreds of feet behind the enemy lines, keeping his lonely vigil, his only means of escape being a gallery 4 ft. 3 in. high and 2 ft. 3 in. wide. Once per tour of duty he was visited by his N.C.O. and the officer on duty.

His tour of duty was 6 hours listening, 6 hours rest (in which he obtains his meals), and then back to duty again. The tour of duty in the line is 4 days, after which he was relieved, and went back for rest for 4 days.

The history of the company shows many acts of heroism performed by those trusty soldiers, to whose efforts has to be placed the successful guarding of Hill 60 through months of dangerous and anxious duty.

MINE-RESCUE WORK.

Hand in hand with the scientific advancement of the different phases of underground warfare went that of mine-rescue work. Due to the number of casualties caused by carbon monoxide poisoning—the result of our own or enemy blows—each army had a fully-equipped mine-rescue school, where men from the various tunnelling companies in the army were trained and then given revision courses at stated intervals.

Equipment of Mine-Rescue Schools.—In the British Army the standard apparatus used for providing the wearer with a supply of factitious but respirable air and allowing the wearer to work in the most poisonous gases were :—

(1) The proto set.

(2) The salvus set. (This set is really a miniature proto set, with a supply of oxygen for ¾ to 1 hour. It is very light and portable, and was chiefly used by officers in rapid reconnaissances after enemy blows.)

In addition to these sets, there was the novita or oxygen reviving apparatus, used for resuscitation work in conjunction with the application of Schaefer's method of artificial respiration to the person gassed.

The Proto Set.—Fig. 19 gives a diagrammatic view of this apparatus. Briefly, it consists of two steel cylinders, each capable of holding 5 cub. ft. of oxygen gas compressed to 120 atmospheres (1800 lb.) per sq. in. A reducing valve is fitted to these cylinders, so adjusted as to pass a regular supply of 2 litres of oxygen per minute, no matter what the pressure may be in the cylinders. The reducing valve delivers the oxygen through a flexible tube to the breathing bag, which is carried on the chest. This bag is of strong rubber contained in an outer bag of canvas. It has two compartments, which, however, communicate near the bottom of the bag through a filter bed of stick caustic soda. This

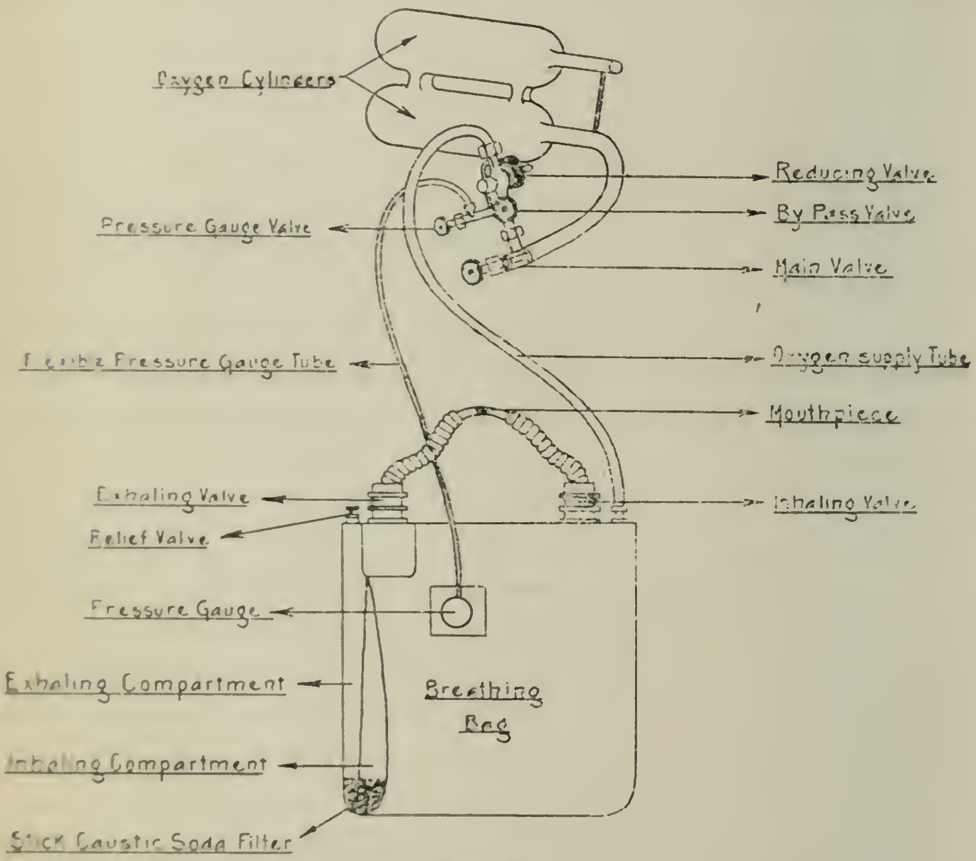


FIG. 19.
DIAGRAMMATIC SET "PROTO" APPARATUS.

bag is fitted with a saliva trap and a relief valve for allowing excess air to escape. The mouth of the bag is closed with metal clamps and wing nuts. From the oxygen compartment of the breathing bag runs a flexible corrugated tube, fitted with an inhaling valve to the mouth-piece, and from the mouth-piece runs a similar tube fitted with an exhaling valve to the saliva trap and thence to the other compartment of the breathing bag.

The mouth-piece has two rubber grips, which are held between the teeth, and a rubber flange held between the lips and the teeth. To ensure this being kept in position it is attached by woven straps to a skull cap.

A nose clip, to prevent breathing through the nose, is also attached.

Connected to the oxygen supply pipe is a flexible tube leading to a pressure gauge, which enables the wearer to read off the amount of available oxygen remaining in his cylinders, and a by-pass valve, by means of which oxygen can be admitted to the breathing bag at a greater rate than that supplied by the reducing valve.

The whole is supported on a broad belt which fits over the shoulders and straps round the waist. The oxygen cylinders are carried on the back, the breathing bag on the chest, and the main valve, reducing valve, and by-pass valves on the left side in such a position as to be readily operated by the right hand.

Operation.—About 4 lb. of stick caustic soda (98.99 % pure) are placed in the breathing bag. The apparatus is then adjusted to the body and the mouthpiece inserted. Breathing is then carried on with the main valve opened about one turn, and when the breathing bag is slightly inflated the nose-clip is attached.

Cycle of Oxygen Gas.—When the main valve is opened the oxygen passes through the reducing valve, then through the flexible rubber tube to the oxygen compartment of the breathing bag. From here it is withdrawn by inhaling into the lungs. The exhaled air passes to the other compartment of the breathing bag, whence it slowly filters through the caustic soda filter bed to the oxygen compartment.

In passing through the filter bed the CO_2 in the exhaled air is absorbed by the caustic soda with the formation of carbonate of soda—

$$2NaOH + CO_2 = Na2CO3 + H_2O.$$

This reaction is accompanied by the formation of heat, and to cool the breathing bag from time to time oxygen is admitted to the bag direct by means of the by-pass, the relief valve being depressed at the same time. In order that the formation of the carbonate may not render the filter bed impervious, the sticks should be well rubbed together from time to time by grasping the bottom of the breathing bag in the hand.

With this apparatus the wearer is enabled to work in a vitiated atmosphere for about two hours on end.

The Novita Set or Oxygen Reviving Apparatus.—This set consists of a single oxygen cylinder with a control valve admitting oxygen to a rubber bag of about 1 cub. ft. capacity. From this bag runs a flexible rubber tube (on which is a clip valve), ending in a rubber face-mask fitted with an exhaling valve.

The person gassed is laid face downwards, the rubber mask placed over his mouth and nostrils, and while Schaefer's method of resuscitation is being applied oxygen is admitted, so that, in inhaling, free oxygen is drawn into the lungs.

Air-Testing.—To test the purity of the air the proto men carried canaries or white mice in a wire cage opened on all sides, on the top, and bottom. The rapid heart-beat of these indicators results in poisonous gases being assimilated to their system much more rapidly than would be the case with the human being, thus giving a reliable indication of a danger point.

The scientific employment of these indicators was not always grasped by the rank and file, as the following incident illustrates.—

We had blown a camouflet of 3000 lb., and as soon as the gallery was pronounced clear we commenced to recover our former position. An air-pipe was placed up to the face, and, to prevent danger from gas cavities when driving through the shattered ground, a white mouse was left with the facemen as an indicator. Judge of the officer's surprise, when, later, visiting the face, he found the mouse and cage suspended in front of the air supply! When remonstrated with, one faceman replied, "Why, the amount of fresh air that mouse will breathe won't harm us!"

Training in the Use of the Apparatus.—All officers and specially-selected men went through a course at the mine-rescue school. Here air-tight galleries of standard size were constructed on the surface with windows, so that the operations could be watched by the instructors. These galleries could be filled with smoke or gas from a small furnace, so that actual conditions of the most rigorous type could be enforced. Operations such as bag-dragging, tamping, and rescuing injured persons were carried out.

In addition, ladder-ways and small openings were included in the system, the nearer to approach to actual conditions.

Lectures on the theory and care of the apparatus were given, and one section of the practical examination consisted in localizing the defects in apparatus. A medical officer gave lectures in mine gases and the application of Schaefer's method of resuscitation in conjunction with the use of the novita set.

Organization in the Trenches.—At every separate mine system two protomen were always on duty on each shift, the whole being under the charge of an N.C.O. They kept all the apparatus in good order, and, immediately on an enemy blow, or after one of our own blows, made a complete inspection of the mine system. All men working below were ordered to come on top immediately on an enemy blow, and to remain there until the galleries were pronounced clear of gas.

In order to economize in apparatus, all proto sets, once the pressure had fallen to 90 lb., were sent back to the mine-rescue school to have the cylinders re-charged and a thorough overhaul of the apparatus made.

DUGOUTS.

The construction of dugouts and machine-gun emplacements formed an important part of the work of tunnelling companies.

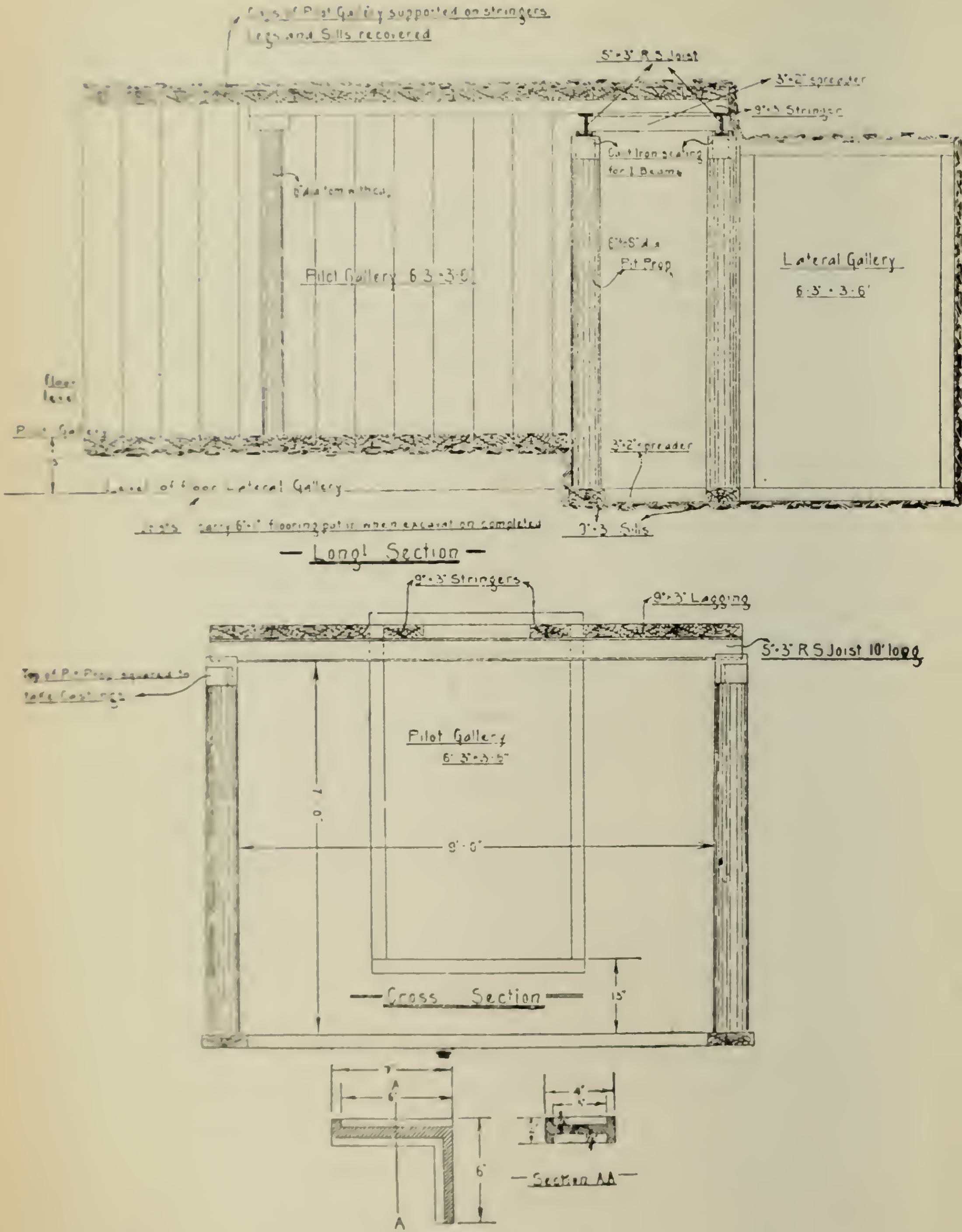


FIG. 20.

METHOD OF DRIVING 9 FT. X 7 FT. DUGOUT WITH PILOT GALLERY.

Details Cast-iron Seating for I. Beams.

Figs. 22 and 23 gives a general lay-out of the standard dugout or machine-gun emplacement.

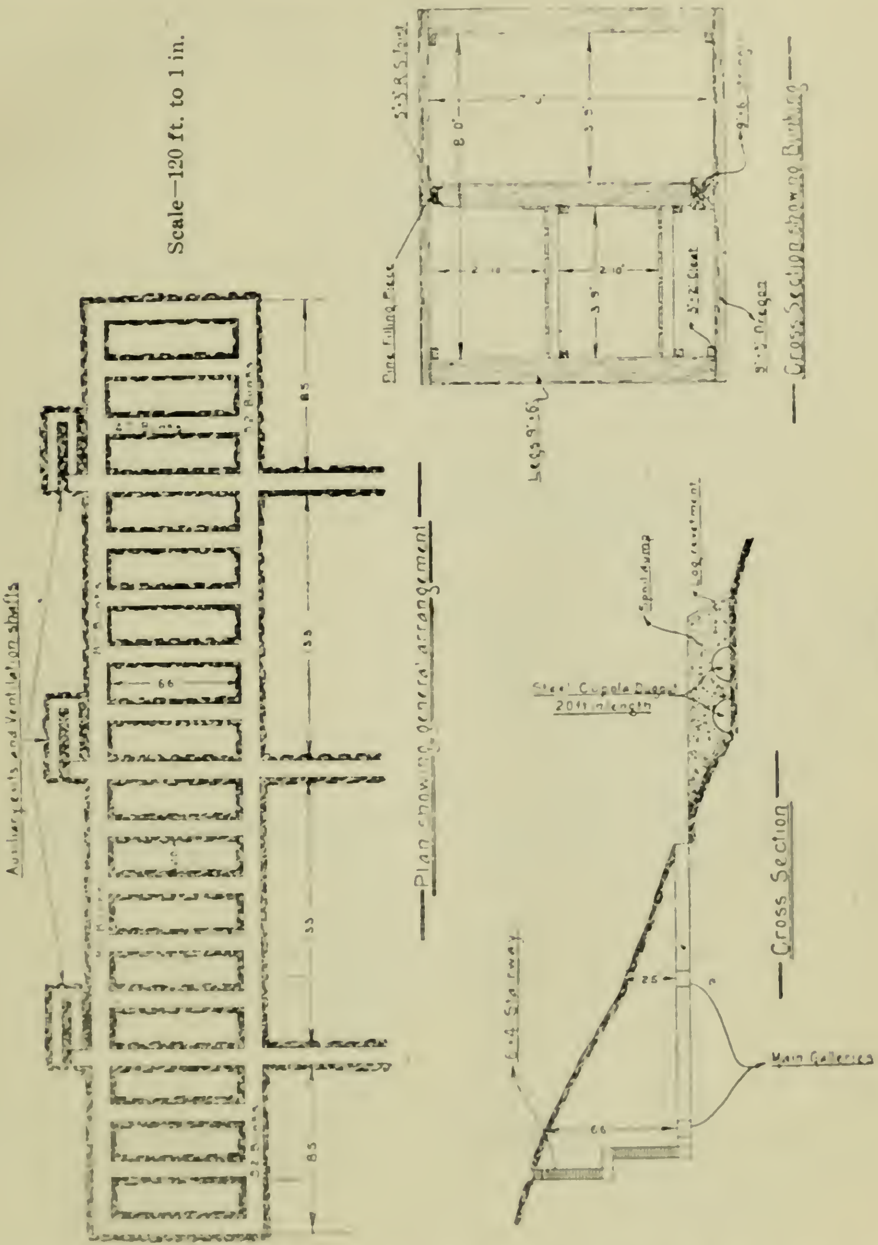


FIG. 21.
DETAILS, HILL 63 DUGOUTS.

The only special feature in the larger dugouts was the size of the galleries. They were 8 ft. x 7 ft. in the clear, necessitating an excavation of 9 ft. x 8 ft. In the average clay this width was too large to carry in one face, as the back invariably bellied.

Fig. 20 shows the details of the method of driving these galleries with the aid of a pilot gallery.

Fig. 21 and 21A show in detail the construction of a 4-way opening-out set used in large dugouts where a centre support was not desirable.

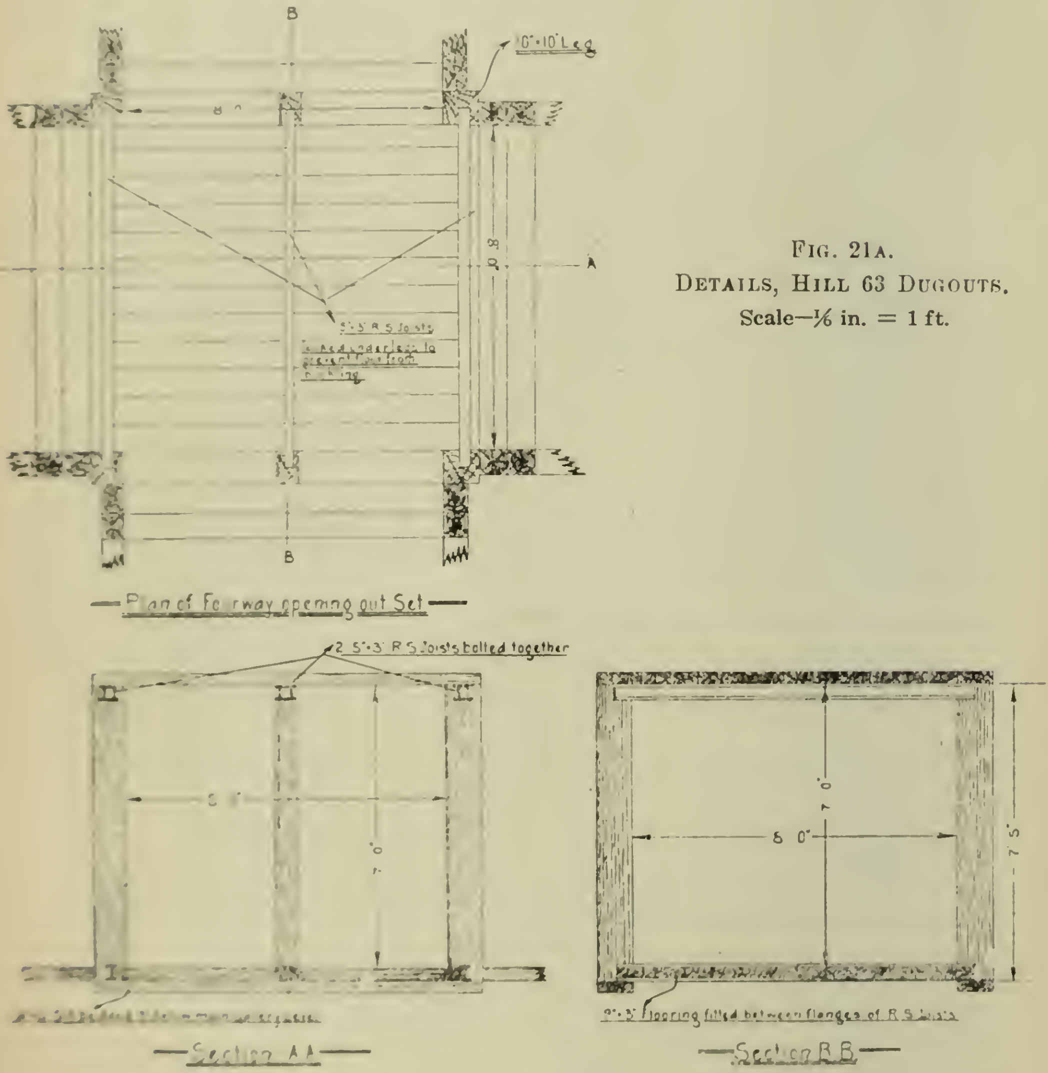

B
0"-10" Leg
8' 0"
A
5"-5" R.S. Joists
B
Plan of Fourway opening out Set
2 5"-3" R.S. Joists bolted together
6' 0"
7' 0"
Section AA
6' 0"
7' 0"
7' 5"
9"-5" flooring filled between flanges of R.S. Joists
Section BB

FIG. 21A.
DETAILS, HILL 63 DUGOUTS.
Scale—⅛ in. = 1 ft.

One particular system of dugouts constructed by this company is worthy of special mention, it being the largest of its type constructed by the British Army. The system was known as Hill 63 Dugout. Fig. 21 gives the details of construction. It

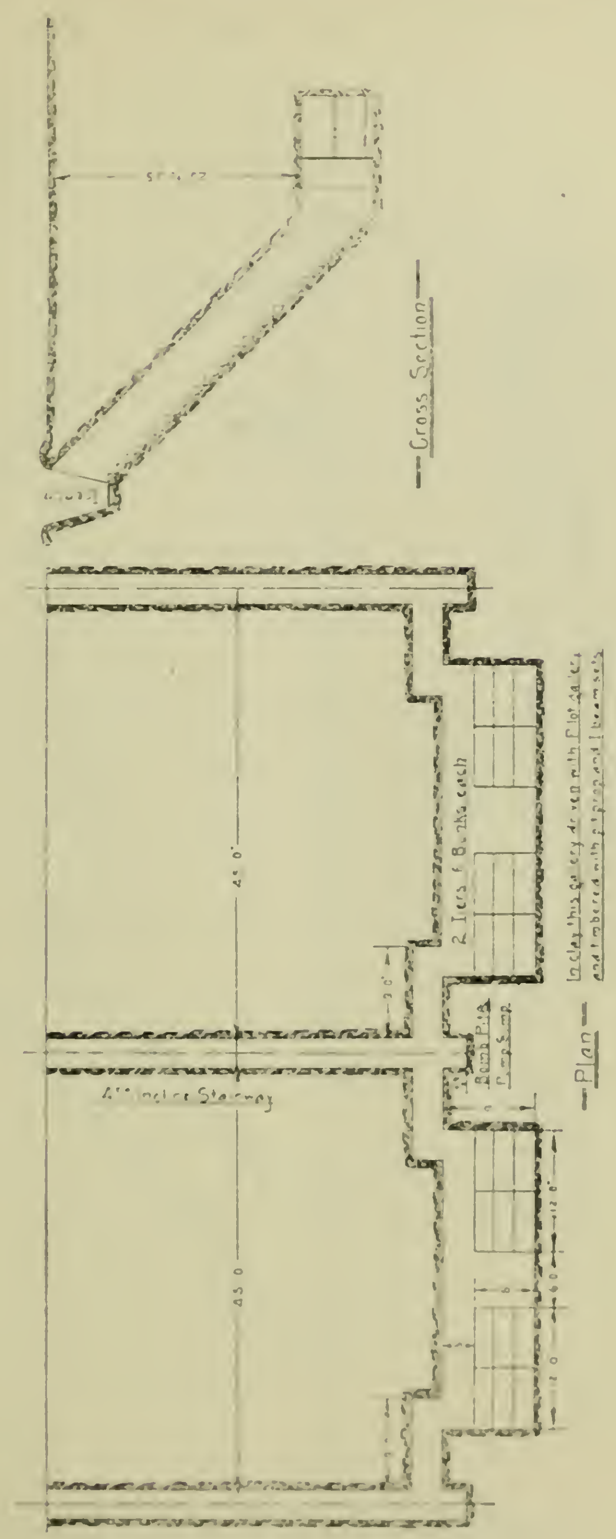


FIG. 22.

STANDARD FRONT-LINE DUGOUT; ACCOMMODATION, 48 MEN.

was constructed at Hyde Park Corner, in Ploegsteert Wood.

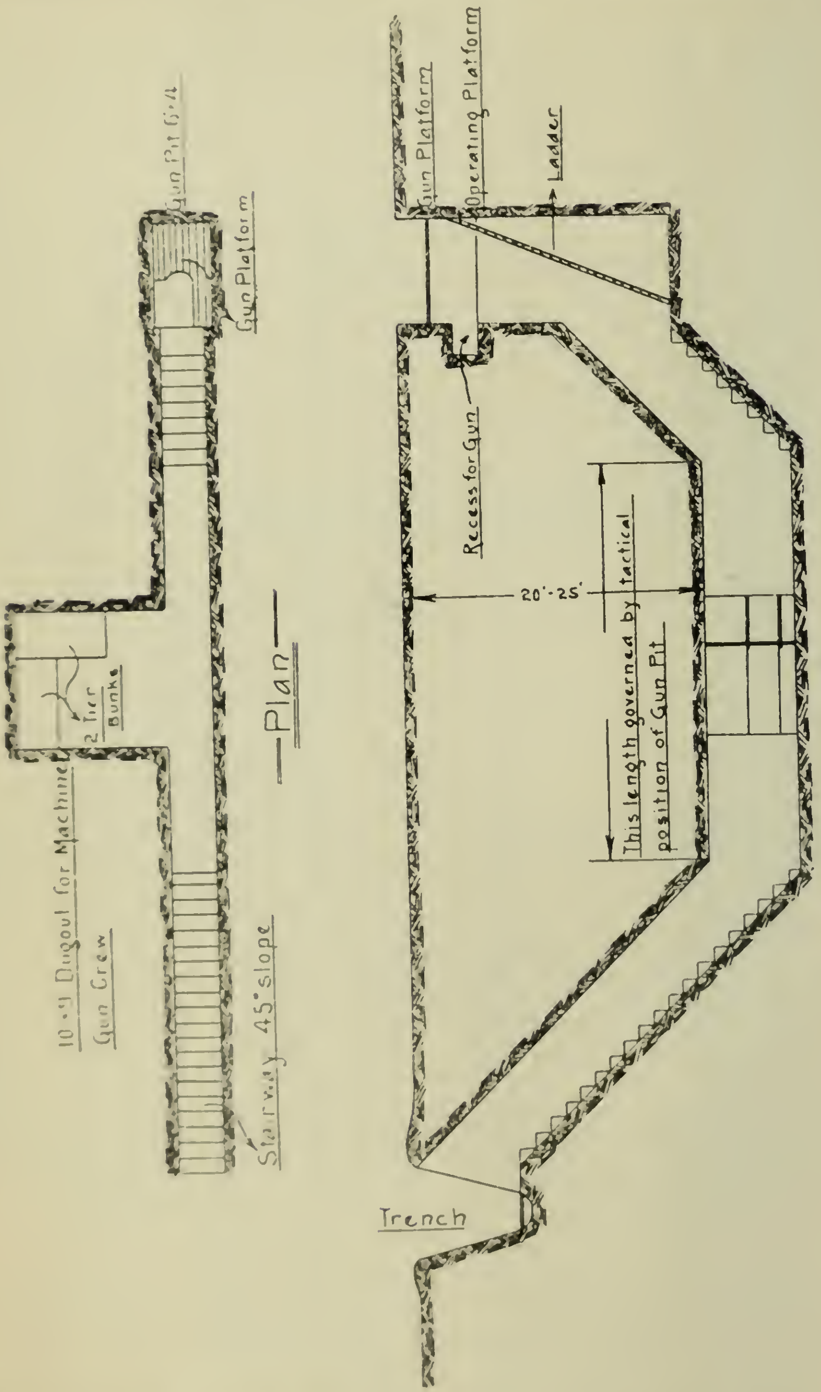


FIG. 23.
STANDARD MACHINE GUN EMPLACEMENT.

The following details show the magnitude of the work :—

Number of working days	63
Average number of men employed, including attached infantry	197
Cubic feet of earth removed	192,588
Average cubic feet of earth removed per man per day	15
Average progress per man per day on the job	.22 ft.
Total footage of 8-ft. x 7-ft. gallery, in the clear	2399 ft.
Total footage of 6-ft. x 4-ft. gallery, in the clear	146 ,,
Aggregate footage	2722 ,,
Sets of timber used	3435 ,,
Entire timbering	520,000 sup. ft.
Bunk sleeping accommodation for	1200 men

In addition, accommodation was made for officers' quarters in steel-framed dugouts placed under the spoil dump with about 12 ft. of cover. The system could accommodate a further 150 ranks in addition to 50 officers. A typical example of progress in smaller dugouts is shown. The dugouts were constructed in Hooge crater for Brigade headquarters prior to the Menin Road battle in September, 1917.

Total hours to complete job	312
Hours delay due to enemy shelling	23¾
Actual hours worked	288¼
Average number of men per shift	27.4
Footages—3 stairways 6 ft. 3 in. x 2 ft. 9 in. in clear, 130 ft. in length	120.3 cub. yd.
Main gallery, 6 ft. 3 in. x 3 ft. 3 in. in clear, 127½ ft. in length	111.8 ,, ,,
Dugouts, 6 ft. 6 in. x 6 ft. in clear, 140 ft. in length	233.3 ,, ,,
Total excavation	465.4 ,, ,,
Cubic feet spoil removed per hour	1.6 ,, ,,

Ground—blue clay.

Spoil sand-bagged and hoisted by truck up the three stairways.

Figs. 22 and 23 illustrate this section.

PROCEEDINGS AUS. INST. M. & M.]　[N. S., No. 37, 1920.

SOME CONTROLLING FACTORS IN FLOTATION.

BY RALPH D. NEVETT.

(Read before the Broken Hill Branch.)

THE object of this paper is to offer some suggestions to assist metallurgists to supervise the operations of flotation plants. We do not yet thoroughly understand what "flotation" is, or "why minerals float," and all attempts that have been made to explain the phenomena have been based on theory or imagination, and have not been capable of substantiation by practical demonstration, or even by laboratory tests; but it is well known that particular minerals will float in a liquid under certain specified conditions, and that some other minerals will not float under those conditions, and that, if a mixture of the two classes of minerals be subjected to those conditions, there will be separation of the minerals, of which one class will float and the other will remain unfloated as a residue. The duty of the flotation expert is to so control the operations and the conditions of the liquor as to obtain the best commercial result from the ore he is treating.

The chief controlling factors in a flotation plant appear to fall under the following eight headings, all of which are important:—

1. Crushing.
2. Rate and regularity of feed.
3. Density of pulp.
4. Temperature.
5. Addition agents.
6. Condition of circuit liquor.
7. Agitation.
8. Aeration.

[This paper is separately bound, and may be, if so desired, detached complete from this number.]

CRUSHING.

The ideal feed for flotation treatment is the true slime which has been the bugbear of metallurgists throughout the ages. This fact should be remembered and taken advantage of wherever possible, although it would not be profitable, as a rule, to continue the crushing operation on crude ore to so great a degree as to make a slime of it. It may be generally accepted, however, that it is bad practice to have any particles remaining on a 40-mesh screen. This is not true in some exceptional cases, as sometimes, for instance, with laminated minerals such as molybdenite and certain copper ores.

Whether the degree of crushing is qualified by classifiers or screens, it is advisable for the metallurgist to assume personal control by having laboratory sizing tests made on regular samples of the crushed feed. In practice it will be generally found that the undersize of a 20-mesh revolving screen, with 45 % screening area when fully loaded, will almost entirely pass through a 40-mesh laboratory screen (I.M.M. standard).

An efficient crushing plant is the first essential for flotation treatment.

There are two reasons why the ore requires to be crushed so that all particles will pass through a 40-mesh screen—

(1) Because the bubble of air or gas which becomes attached to a particle has not sufficient power to float larger particles of mineral which are produced by any other coarser crushing. If, moreover, a bubble of gas were large enough to float a larger particle, the resistance which it would offer to the flow of the pulp would probably cause it to be wiped off and removed from the particle before it had time to reach the surface of the flotation bath.

(2) Large particles of ore, when being hurled around in the agitation zone of the flotation vessel, do considerable damage in hindering aeration by cutting bubbles of gas off other particles of mineral.

RATE AND REGULARITY OF FEED.

It is essential that the rate of feed going into the flotation plant should be as nearly regular as possible each second of time. There is nothing which interferes so much with treatment as irregularity in the rate of feed and irregularity in the quantity of liquor which passes through the plant from moment to moment. It is a simple matter to make the rate of feed and liquor regular by means of a large agitator or Dorr thickener placed at the head of the treatment vessels. This agitator or Dorr thickener can store quantities of feed supplied to it in an irregular manner by the preparatory plant and deliver it in a regular flow at its discharge to the treatment plant. This storage of slime also enables the flotation plant to be operated continuously through any small stoppages of the preparatory plant.

DENSITY OF PULP.

It is necessary that the feed should be introduced to the treatment plant, in the form of pulp, at a predetermined density which is best suited to the process. The density should be maintained at a regular rate from moment to moment just as strictly as the rate of feed itself.

Extensive experiments were made on the dump material flotation plant at the Junction North mine for the purpose of determining a suitable density and rate of feed. It was found that variations of density had an important effect upon the rate of feed that could be treated. When the density was 56 % solids it was impossible to treat more than 8 tons of dump material per hour, and then only with poor metallurgical results. When the density was reduced to 35 % solids the same plant treated 24 tons of dump material per hour with excellent metallurgical results. This fact alone shows how simply a flotation plant can go wrong.

It will be seen from this that the rate of feed and density are allied with each other and complementary, and should be kept under constant control. The following is a quick and reliable method for controlling the density of the pulp in a flotation plant :—

A tin is made to hold 1000 ccs. of water up to a mark, say, about half an inch below the top. The tin is dipped quickly into the flowing pulp and filled up to the mark. It is then weighed, using a counterpoise for the tin. The shift boss or operator should make such a density test at intervals not greater than 15 minutes. The weight of the pulp would be, say, 1350 to 1400 grm., which represents about 30 to 34 % of solids in the pulp at the dump material treatment plant at the Junction North mine. If the weight is greater than 1400 grm. the operator adds water to the pulp as it leaves the Dorr thickener.

TEMPERATURE.

With some ores flotation can be carried out in the cold, but a good many ores require heat to a limited extent. Sometimes, with ores containing several minerals, it is necessary to have a little heat for the flotation of one mineral and a greatly increased amount of heat for the flotation of the second mineral. At the dump treatment plant at the Junction North mine in the selective flotation treatment of lead and zinc sulphides by either the Bradford process or the P.-S.-N.* process, it has always been necessary to watch the temperature of the pulp very closely. In the lead section the most suitable temperature was 89° to 90° F. Even a single degree over 90° F. has been detrimental to the grade of the lead concentrate, as zinc sulphide commenced to float with the lead concentrate with the rise in temperature. In the zinc section the best results were obtained at a temperature of 135° F. with the Bradford process, and at a temperature of 125° F. with the P.-S.-N. process. If the temperature is allowed to drop to 130° F. in the former case, the zinc concentrate is not completely floated, and a loss is made in the residues. No benefit is gained by increasing the temperature above 135° F.

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* Palmer-Seale-Nevett process.

Metallurgists like, wherever possible, to treat the ores with as little added heat as possible, to save cost. Wherever heat is required, attempts are made to utilize exhaust steam of engines and other sources of heat, if possible. It is not always possible, however, to make use of exhaust steam in this way, even if same may be available. The favourite method of heating, although perhaps the most expensive method, is by the introduction of high-pressure steam direct from the boilers to the pulp, which is always very convenient and easy to manipulate, and has quick and effective results, requiring only the operation of a valve from time to time for keeping the temperature of the pulp constant. The ease with which high-pressure steam can be obtained by the operator, and the fact that extra temperature does no harm in zinc treatment, makes it liable to be wasted very considerably. A close watch requires to be kept on the steam consumption in this way, as it might, besides being wasteful in costs, tend to overload the boiler plant if it is otherwise working at high pressure.

ADDITION AGENTS.

In all flotation plants it is necessary to add some chemicals. The point at which such chemicals should be added is an important one, and should be determined carefully. It is a matter of vital importance that the valuable minerals in the pulp should be in a properly prepared condition suitable for floating before the pulp enters the flotation machine. For the purpose of ensuring this, it is obvious that whatever chemicals are required should be added to the pulp at least before it reaches the flotation machine. Frequently the purpose will be served if the chemicals are added in the agitation machine, but sometimes it is advisable to add them to the pulp before it reaches the agitation machine.

When acid is required, generally speaking the best place to add it is in the agitation machine, although it may sometimes be added directly to the flotation machine. Frequently acid produces gases, such as sulphuretted hydrogen, by action upon the pulp, which are harmful to flotation, and it is advisable to let these have time to disappear before the pulp reaches the flotation machine.

Oil is not an essential reagent in flotation, but when it is used it should be added far enough back in the flow to ensure its emulsification in the pulp before it reaches the flotation machine. When it is not thoroughly emulsified, oil is distinctly detrimental to flotation. Oil should never be added directly to the flotation machine, but may be added in the tube mills or other grinding machines or in the return liquor pump or in the agitation machine, as may be found best in practice.

CONDITION OF CIRCUIT LIQUOR.

It is usually convenient to employ the ordinary mill-feed water for making up flotation circuit liquor. The first essential is that this water shall be clean—that is, free from sediment. Such feed water is usually drawn from the underground drainage system, to which has been added some fresh water from the surface rainfall supplies. The mine water would probably contain a certain amount of salts in solution, and in some cases the proportion of salts in solution would render the water unsuitable for flotation.

The mill water coming in contact with the ore usually dissolves a good deal of the soluble impurities from it, and by the time the water reaches the flotation plant it might be too heavily charged with salts to make it suitable for acting as a flotation circuit liquor.

The flotation circuit liquor requires some properties other than cleanliness to ensure its successful use in a flotation plant, but it is not clear what those properties are. For a long time it was thought that it was necessary to have at least a comparatively large definite quantity of salts in solution, and that this was the main controlling factor in the constitution of a good circuit liquor for flotation. From many tests carried out at the Junction North mine, it would appear even yet as if the quantity of salts, and kind of salts, in solution exerted an important influence on the flotation operation. It was noticed sometimes, when the flotation plants were not working well, that the quantity of salts in solution had either dropped below 1400 gr. per gal. or had risen above 2600 gr. per gal. It would seem from the various tests that the best results were obtained when there were about 2000 gr. of salts per gal. in the solution. The salts were mainly salts of manganese, zinc, iron, and calcium. It would be a very difficult matter to carry out a set of tests either in the laboratory or in an operating plant to prove the effect of salts in solution. The ore itself containing soluble salts would, as soon as it comes in contact with pure water, immediately provide some salts in solution.

A good deal of work has been done at the Junction North mine and by other investigators to endeavour to determine the actual effect of certain specified salts in solution, and a good deal of interesting information has been collected; but it has never yet been shown that any of the common salts which naturally go into solution in the Broken Hill treatment have a very marked influence upon results, unless present in excessive quantities, and none of the salts known to exist in the circuit liquors in Broken Hill have anything like so great an influence upon the treatment as to explain the reason why some flotation liquors are energetic and others dull in their action. It is distinctly noticeable, when flotation work is going on successfully in the plant, that the flotation liquor has some property which has never yet been thoroughly defined, and it seems to be a physical property denoting energy which has been instilled by some means into the circuit liquor. Sometimes the nature of the liquor can be corrected by alteration to the oiling, sometimes by alteration to the application of acid. The new P.-S.-N. process claims to correct the conditions of the liquors in many cases by addition of elemental sulphur.

If oil exists in the circuit liquor it must be emulsified. Free oil is very detrimental to flotation work, as can easily be seen in the Cascade process. If a few drops of oil are admitted to the first Cascade vessel its effect will be seen on each of the following Cascade vessels of the series in killing the float which was just previously there.

AGITATION.

Agitation is beneficial in all methods of flotation of all classes of ore. Some classes of ore, however, do not require so much agitation as others, and calcitic ores treated by purely acid processes usually require only a moderate degree of agitation before treatment. The quantity of calcite present in the ore need not be more than a few pounds per ton. The acid readily sets free the CO_2 gas which, being nascent, rapidly attaches itself to the mineral particles and floats them. The intimate association of the calcite in the ore ensures successful gassing. Such ores as do not contain calcite or any other carbonates require treatment by agitation/aeration, by which the atmospheric air is beaten into the pulp, to cause the attachment of bubbles of air to mineral particles. The M.S. machine was originally designed for this purpose, and later on the Owen patent and Lyster patent showed other means by which it could be carried out more effectively and more completely. The agitation should be carried out in the treatment vessel so that the mineral can rise to the surface of the vessel and be removed without having to travel a greater distance than is absolutely necessary, or, in other words, to avoid overtaxing the ability of the bubble to retain its hold on the mineral particle for leading it out of the flotation bath.

The author is, however, strongly in favour of providing some kind of machine at the head of the treatment; for instance, a vortex mixer or a mineral separation mixer, or a larger agitation machine, to provide that the pulp shall be thoroughly agitated and partially aerated before it enters the treatment vessel. This pre-agitation aeration incorporates oils, reagents, acids, &c., and probably causes some beneficial effect by oxidation of some of the substances, and so saves the first-treatment vessel from being wasted on this work. It might be, too, that some deleterious substances are formed immediately upon application of the acid and reagents, such as noxious gases like H_2S, which, in this preliminary partial agitation/aeration, are either driven off or altered to make them innoxious, and in this preliminary agitation machine chemicals or acid or perhaps oil may be added, the temperature being controlled so that when the pulp enters the flotation machine it is ready for separation of the valuable minerals. It is even advisable to add the chemicals or oil or acid to the pulp before it enters the preliminary agitation machine.

With some simple ores very little agitation is required before the pulp passes to the flotation machine, and, in such cases, if the pulp is lifted by bucket elevators direct to the flotation machine, sufficient agitation will be provided by the elevators for successful separation. In that case the chemicals and other reagents may be added, perhaps, at the boot of the elevator. The bucket elevator may be looked upon as a first-class agitator, although the period of agitation provided by it is very short.

If the pulp requires much acid or heat added to it, it is advisable to have the agitation vessel at the head of the flotation machine besides the elevator, because in such cases the elevator belt would suffer severely if it handled hot or acid liquors.

Agitation is always beneficial to flotation, and in most cases it is absolutely necessary. It has a cleaning effect on the particles, and, if oil is used, causes a greater emulsification and distribution of the oil. To ensure a more complete flotation of the particles, it breaks up the bubbles of air and distributes them in a very free state of division throughout the pulp in such a manner as to give every particle of mineral a chance to become attached to air bubbles.

AERATION.

Aeration means the introduction of air into the pulp in a finely-divided condition so as to form a froth, in order that the particles of mineral may become attached to finely-divided air bubbles, by means of which they are floated up to the surface of the flotation bath and removed across the periphery as a separate concentrate. Air for aeration was originally introduced into the mineral separation machine by being sucked down to the impeller from the surface through the vortex and disturbance caused by the agitation. The quantity of air so converted into froth was always indefinite and not under control, and for this reason flotation results were very changeable. It was necessary to have the agitation/aeration zone in another vessel separated from the flotation bath, because the latter required a quiescent surface, which could not be provided by the former. This was a very severe handicap, as it required the bubble to travel a very great distance before it could be rescued at the surface ; consequently, only the most powerful methods of flotation could be used with it, such as would develop combined flotation and not permit of any selective action.

It was found by Owen that if agitation/aeration were carried out in the flotation bath itself the bubble would have a very much shorter travel, and much more delicate flotation work could be carried out. The effect of this was to permit of selective flotation on one mineral in preference to another. By means of the Owen process, air was either sucked in by impellers or pumps, or was introduced as compressed air and delivered to the impeller in such a manner that it could be most effectively beaten up into a foam.

Later on, at the Junction North mine, it was found that definite control could be obtained to govern the quantity of aeration introduced into any pulp, and measurements could be obtained of the amount of aeration by means of a steelyard or an ordinary water-gauge tube, graduated and placed outside the flotation vessel and connected with it. It was afterwards found, by means of the Cascade process, that aeration could be adequately obtained by means of entanglement with pulp as it fell down open pipes.

It is essential that the air should be completely atomized in the pulp and not allowed to be distributed through the pulp in the form of comparatively large bubbles. This must be carefully watched when aeration by compressed air is adopted. If the supply of compressed air is too great through any one delivery pipe, then the air is distributed throughout the pulp in the form of large bubbles, which are unsuitable for flotation. These large bubbles float rapidly to the surface and disturb the quiescent zone, so that some of the float already there is caused to sink again and some of the gangue is caused to overflow the periphery and spoil the concentrate. Compressed air must be added in such a way that it enters the pulp in the maximum zone of agitation of the impellers. The force of agitation at that point will determine the amount of air which may be effectively taken from the supply pipe. If it is desired to atomize a still greater quantity of air than can be dealt with from one supply pipe, it is possible to gain such an increase in any particular flotation machine by increasing the number of air-supply pipes around the impellers or by increasing the speed of the impellers.

In the Cascade process the air is drawn in and entangled by the pulp as it drops down the vertical pipe and becomes atomized by the splashing of the pulp in the impact, which occurs when the pulp hits the surfaces of the liquor and metallic parts of the flotation machine. It is generally advisable in the Cascade process to have a cup placed below the bottom of the vertical pipe to intensify the impact.

DISCUSSION.

MR. E. T. HENDERSON said, as regards soluble salts, it was found on the Broken Hill Proprietary plants that they could keep them as high as 7000 to 8000 gr. per gal. without any detrimental effect to the results. He considered that the organic matter was a more serious proposition. If H_2S were passed through the solutions, a precipitate not unlike CdS was obtained if organic matter were present. With this filtered off, and the solution used for flotation, excellent results were secured. The acidity of the solutions was 1 %. He was against the use of compressed air in any form, as he was of the opinion that if the air were sucked in it was broken up much better.

Mr. Ralph D. Nevett, in reply, said care had to be taken in removing organic matter by H_2S, as it would be found that there was a great tendency to precipitate salts of manganese and zinc. As regards compressed air, they found in the Junction North plant that more slime could be treated by this means than by any other. They also found that each horizontal machine, when allowed to work on the quantity of air that the impellers would suck in, would only treat about two tons per hour, but, when supplied with compressed air up to the maximum amount, that the impellers would atomize, each machine would treat 6 tons per hour.

Mr. W. B. Chomley said he would like to make some remarks in reference to Mr. Nevett's interesting paper, and it must be understood that such comments were made chiefly in the light of his experience with the Zinc Corporation. Taking some of the points in the order in which they occurred, the first that called his attention was the statement that the natural slime was the ideal one for flotation. That was distinctly in contradiction to his experience on the current-ore-slime plant at the South Blocks. Naturally, slime usually contained a large proportion of colloids and ore in a very fine state of division, which appeared to form a stiff froth, which floated over and lowered the grade. Prior to the erection of mechanical thickeners there the slime was imperfectly settled in a series of cones, which left a cloudy overflow. This was run to an accumulation dam. It was a significant fact that since the installation of the thickeners, and the consequent retention of that part of the slime in the feed, the results had not been so good as heretofore. In regard to the question of the size-limit of ore particles, without committing himself to any arbitrary figure, he noticed that large lead particles generally were carried down to the zinc box, and that the zinc lost in the residue was the coarsest. It seemed to be generally accepted that the flotability of a mineral particle, other things being equal, depended upon the ratio of its surface-area to its weight, and from that it may be inferred that the conditions which were suitable to float a small piece of an active mineral, such as galena, would not lift larger grains of the same mineral; and when conditions were intensified enough to accomplish that, the lighter particles of a less active mineral, such as zinc-blende, would commence to float. Regularity of feed seemed to be one of the most important points in connection with preferential flotation, although when dealing with a mixed float irregularity of feed flow had not the same chance of doing harm. On the Zinc Corporation re-treatment plant, where a mixed float of lead and zinc was taken off for subsequent separation by gravity concentration, the hourly tonnage might be varied over a wide range without causing any deleterious effects. But on the South Blocks, where the current slime was treated by a preferential process, the case was different. Any sudden alteration in the feed-flow there had the effect of changing the lead-zinc demarcation point, and unless measures were immediately taken to meet the altered conditions, considerable mixing of the products took place. He could not endorse the author's recommendation for the use of a thickener for a storage tank for slime. Having had some experience in running a cyanide decantation plant, he had grave doubts as to the possibility of obtaining a regular stream of pulp from the underflow of a Dorr type of thickener, either as regards volume or density. An agitator made an efficient buffer to equalize irregularities of flow and density, and consumed very little power. Sudden alterations in the density were fatal there, as the boxes on the South Blocks were of the gravity-level type, and any change upset the balance and caused some cells to flow over and others to drop too low. He knew that many devices had been made to overcome that difficulty, such as, for instance, a sliding lip, but he had yet to see one that had stood the test of continuous working conditions. As regards the addition of reagents, the author recommended that they should be added as far back in the process as practicable, preferably to the tube mills. Would he apply that practice to a plant where perhaps only one-fifth of the ore, or less, went to the flotation plant? If, on the other hand, some special appliance, such as a vortex mixer, was used as an emulsifier, the power consumed was comparable to that required to run a small flotation unit; so why not make some use of it as a concentrator? In other words, why not add the oil to the feed launder, even if it did lower the efficiency of the first unit? The author's remarks in reference to the effect of different feed waters, and the difficulty of locating the determining factors, coincided with the experience on the South Blocks plant. Possibly the presence of the various salts was only incidental, and merely masked the presence of some agent or quality which was not capable of being detected by an ordinary analysis. Apparently that was one of the many things in connection with flotation which must be taken for granted. In the absence of any accurate knowledge as to the underlying principles of this art, it must remain something like the state in which the study of astronomy was prior to the discovery of the law of gravitation, when the heavenly bodies seemed to move hither and thither in defiance of any possible theory.

Mr. Nevett, in reply, said they did better work with slime than with any other material. The trouble at the Zinc Corporation might be due to dirty water with suspended residues. In respect to regularity of feed, the dump plant at the Junction North mine would be hopeless unless it could be run with a regular feed. Mr. Chomley, he thought, was under a misapprehension in regard to the remarks in the paper about using a Dorr thickener as a storage. They at the Junction North run their thickener for their dump material plant, with no overflow, so it was practically a large storage tank, and not a thickener in the true sense of the word. With regard to reagents, in the Junction North plants the tube mills were only used to crush the feed to the flotation plant, and, therefore, did not do the work of most tube mills, such as grinding feed to Wilfley tables, from which afterwards the tailings went to the flotation plant. As regards the addition of oil far back in the plant, he would point out that if it were added close to the flotation machine there was a tendency of getting free oil into the machine. In some cases they had added it as far back as the return circuit liquor pump. By thus adding the oil a long way back, the air had a better chance of getting to it, and the results were better. The vortex mixer referred to broke up the lumps of dump slime before going to the storage thickener. He did not recommend the practice for current slimes. With regard to circuit liquor, as mentioned in the paper, they corrected the circuit water by the addition of elemental sulphur.

Mr. T. Read mentioned that he would like to ask Mr. Nevett whether he had any figures in regard to how much air per ton he used, especially as a comparison between the Cascade plant and plants using mechanical mixers. They had experimented on the South mine on the subject of compressed air, and found that as long as it was properly atomized a good float was obtained, but they found it necessary to put in a trap to collect any mineral oil. They had no difficulty with the use of a blower on both lead and zinc flotation. Their class of machine took about 2000 cub. ft. of air per ton treated. With regard to circuit water, they (on the South mine) ran on a neutral circuit, and found no difficulty with the salts up to from 450 gr. to 600 gr. per gal. The salts in solution consisted of 70 % $CaSO_4$ and calc. chloride, with but 2 gr. of iron per gal. In respect to slime, 97 % of the South mine slime would go through a 200-mesh screen, and they had no difficulty so long as the crude ore was pushed straight through the mill, otherwise the galena became coated, due to formation of colloids in the gangue material. Regarding thickeners, he was of the same opinion as Mr. Chomley in the matter of the use of a Dorr thickener as an equalizer. Usually in a Dorr thickener there was only a bed of about 8 in. of pulp slime, so it was not an equalizer. A nest of them would be required for such a case. However, he noted from Mr. Nevett's reply to Mr. Chomley that he had no overflow on it, hence it was not a true Dorr thickener, but an agitator. At the South mine they were not troubled with variations in volume of the feed due to the type of machine used. Each vessel of the unit was automatically controlled by a float. Their experience at the South mine in regard to density of pulp was similar to that of Mr. Nevett's. They got the best results with a pulp containing about 45 % solids. At 50 % atomization is incomplete.

Mr. Nevett said he had no definite figures in reference to the amount of air used per ton either in the cascade or mechanical mixing plants.

Mr. Andrew Fairweather asked Mr. Nevett whether he thought the change of level in the boxes caused bad work.

Mr. Nevett replied in the affirmative, and said if a regular feed were not obtained, control (except automatic control) could not be secured. Automatic control was all right for slight variations.

Mr. A. W. Wincey congratulated Mr. Nevett on his excellent paper, and thought he had touched on all the essential points. Flotation was an intricate means of concentration, as the conditions varied for each class of ore. His (Mr. Wincey's) opinion was that crushing was the most essential feature. The size of the particles depended upon the condition of the crude ore, whether fine-grained or not. His experience was that the best results were obtained on slime. Mr. Chomley's difficulty with slime was probably due to dirty circuit water. Regularity of feed was most imperative, for if the feed were light zinc came up with the lead, and if too heavy a good deal of the lead would find its way to the zinc plant. With reference to salts in solution, on the Central mine some years ago, when the original mineral separation boxes were installed and H_2SO_4 and oleic acid were used, it was essential to keep the salts about 3500 gr. per gal. They used a hydrometer for that purpose, and the spitzman could tell from a scale the condition of the liquor. They lost the separation if the salts got above 3500 gr. unless they were running on an acid circuit. With regard to the size of particles, he would like to ask Mr. Nevett whether he found that large particles were detrimental.

Mr. Nevett did not intend to infer that the order in which he had mentioned the controlling factors was that of importance, but considered that they were all necessary. As regards large particles, he was convinced that they were detrimental, as they prevented the attachment of air bubbles to the metals.

MR. G. E. GABRIEL said the author stated that when oil was not thoroughly emulsified it was distinctly detrimental to flotation. M'Graw stated that "a pulp-oil-acid combination is not an emulsion in the true sense of the word, as a true emulsion is a colloidal condition and also a deflocculent condition. The function of H_2SO_4 has not been satisfactorily explained, but we know that it is a flocculating agent, and therefore it prevents emulsification."

MR. NEVETT, in reply, said what he meant was that the oil must not exist as a free oil. M'Graw, in his book, "The Flotation Process," stated :—"(1) Sulphuric acid prevents emulsification; (2) ferrous sulphate has no action to prevent or help emulsification ; (3) sodium chloride stabilizes and increases emulsification." Whether he was right it was hard to say. As ferrous sulphate had no action, it was reasonable to expect that zinc and Mn sulphates behaved in the same manner. Those three salts, with sodium chloride, made up the bulk of the salts in solution, consequently the water would be a good one to stabilize and increase emulsification. Using that water in a test with a few drops of eucalyptus, and agitating the water and oil for some time, then allowing it to stand for a few hours, the oil would not separate from the water. That meant an emulsion of oil and water had been formed. This liquor made a very good flotation medium, and would give a good float of sulphides without the addition of acid. Lunge, on page 663 of his book, "Coal-tar and Ammonia," Part 2, mentioned that emulsions of tar oils could be produced by H_2SO_4, which seemed to disprove M'Graw's argument.

MR. H. V. SEALE wished to ask Mr. Henderson what was the best quantity of salts in solution for (1) lead and (2) zinc.

MR. HENDERSON said he found the higher the salts the better results obtained in both cases. He did not believe that there was anything in the theory that salts were detrimental.

Mr. Nevett asked Mr. Henderson what water was used at the Proprietary to make up for the deficiency in circuit water.

Mr. Henderson said that no fresh water was used, but mill water, which came from underground.

Mr. Wincey said it seemed to him that the reason for the Junction North and the Proprietary using solutions low and high in salts respectively was due to the Proprietary using the SO_2 process. They found by experience on Block 10 that if the salts got high and they did not use SO_2 they could not get a high-grade lead concentrate.

Mr. Nevett, in reply, said when the tests mentioned in the paper were made they were using the hypo. process, which formed SO_2 in the pulp.

Mr. Wincey said that would have the same effect as the SO_2 supplied from burning sulphur in the Bradford SO_2 process.

Mr. Henderson: No, not quite.

ISOMETRIC MINE PLANS.

H. E. CLAYTON.

Discussion.

MR. JOHN S. FOXALL wrote:—Mr. Clayton in his paper on the above subject (Proceedings, N.S. No. 34) made an assertion which should not be allowed to remain unchallenged. On the top of page 10 appears the following statement:— "By viewing the box at a depression angle of 45°, all the dimensions are disclosed and the box may be projected on isometric co-ordinates " and lower down on the same page :— " An isometric plan, being virtually a projection on a plane inclined at 45°, the nearer the dip approaches this figure so is the outline of the stoping more truly shown." Those statements embody an inaccuracy which would be misleading were an isometric plan to be constructed to suit a special case, i.e. the case of a mine whose lode dipped at 45°, or approximately 45° and it would be found that in such a plan the outline of the stoping would not be truly shown. The reason for this is that the depression angle at which an object is viewed in order to get an isometric projection is not 45°, but 35° 16′, which will be proved, and consequently the plane on which an isometric plan is a projection, being at right-angles to the depression angle is inclined at an angle of 54° 44′ to the horizontal. The simplest form of an isometric projection is that of a perfect cube. Let

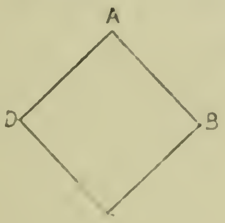

FIG. 1.
PLAN.

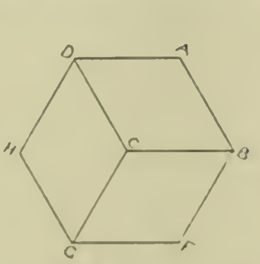

FIG. 2.
ISOMETRIC PROJECTION.

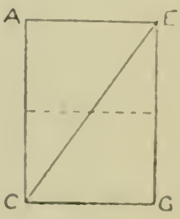

FIG. 3.
SECTION.

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the square A.B.C.D. (Fig. 1) represent the plan of a cube, Fig. 2 the isometric projection of the same, and Fig 3 a vertical section though A.C. Looking at Fig 2, it is obvious that the line of sight, which makes with the horizontal plane the depression angle at which the object is viewed, passes though two points which coincide on this figure at C. The second point is at a distance below A in Fig. 1 equal to an edge of the cube, and may be seen in Fig. 3 as the point E, so that in Fig. 3 the line of sight passes through C. and E., and as the line A.C. represents the horizontal plane, the angle of depression is seen as the angle A.C.E. Now, A.C. being the diagonal of the square, A.B.C.D. = A.E. x $\sqrt{2}$ as A.E. = the side of the square, therefore the tangent of A.C.E. = $\frac{A.E.}{A.C.} = \frac{1}{\sqrt{2}} = .7071$. This gives a value of 35° 16′ for the angle A.C.E.

Papers and Discussions.

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THE RECOVERY OF ZINC FROM LEAD BLAST-FURNACE SLAGS.

BY GUY COURTNEY.

As the question of zinc recovery from lead blast-furnace slags has lately become such an important subject with lead metallurgists, the following description of some of the work carried out in this connection by the Sulphide Corporation, at Cockle Creek, should prove of interest to those concerned.

Early in the life of the works it was realised by the metallurgical staff that a very wide field for investigation lay before them. At the head of these was the late Mr. F. H. Evans, and it was due to his work and suggestions that the question has grown from a mere hypothesis to a commercial undertaking, in so far as these works are concerned.

A great deal of the early work was carried out in the form of small laboratory experiments, those giving the best results being ear-marked for subsequent trial on a larger scale.

One of the main obstacles in the way of research was the lack of any data or information of similar work done in other

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[This paper is separately bound, and may be, if so desired, detached complete from this number.]

countries, but in spite of this and the fact that the staff had their hands full, with more important work, a certain amount of progress was made. Thus was the foundation laid for the larger experiments carried out during the last four or five years.

In 1908 a patent was filed by the late F. H. Evans in conjunction with P. A. M'Kay, which had for its object the expulsion of zinc from lead blast-furnace slags, the operation being carried out either in a blast furnace or reverberatory furnace supplied with tuyeres. A converter is also proposed, the reduction of the zinc being accomplished by blowing in carbonaceous material in a finely divided condition, or carburetted gas through the molten slag.

One of the earliest attempts made at Cockle Creek to drive the zinc from the slag was some fourteen years ago. Compressed air was blown in under the surface of some molten slag. The resultant ebullition drove off large volumes of fume, but, owing to the chilling effect of the cold air, the test could only be maintained for a few minutes. A little later this method was again tried, but with certain modifications. An iron pipe was procured and lined with firebrick, leaving an opening 15 in. in diam. and 4 ft. deep. Four inches from the bottom three tuyeres were fitted, equally spaced round the circumference. Attached to the tuyeres were three reservoirs for powdered coal. In starting, the air and coal dust were turned on and hot slag poured in to a depth of about 12 in. above the tuyeres. The agitation, brought about through the blast of air and the combustion of the coal, drove off dense volumes of fume. This continued without abatement for about 45 minutes, which was as long as the supply of fuel lasted. Without proper means of handling the powdered coal, it became a difficult matter to insure a constant stream being blown in with the air, as at this period little was known of the methods and appliances now in use for the handling of powdered fuel. The zinc driven off was only about 1%, but a marked increase in the temperature of the slag was observed This would no doubt have reached the 1600°C, which was afterwards found to be so important a figure in all the tests.

When this experiment was repeated the same results were observed. These tests anticipated the patent subsequently taken out, and in a great measure the new methods now being employed in one or two American and Japanese works, whereby powdered fuel is fed to the copper blast furnaces through the tuyeres.

The Reverberatory Furnace.

At a later period information was obtained from Europe, which led to the belief that the problem had been successfully solved. Two processes were in operation; one using briquettes in a blast furnace, the other utilising the hot slag as it was tapped from a lead blast furnace into a reverberatory furnace. In the latter operations two reverberatory furnaces were used, one of 20 tons and the other of 5 tons capacity. Into the former the slag was tapped from the blast furnace, and given a good strong firing. At intervals of 2½ hours the tap hole was opened and enough slag allowed to run to fill the smaller or 5 ton reverberatory. At this stage a certain amount of limestone and coke was added, and strongly fired for another 2½ hours. At the end of this period the zinc should have been expelled from the slag.

An experiment at Cockle Creek on the reverberatory method differed from the European tests in that only one furnace was used and the slag was introduced cold instead of hot. Charges of 10 tons were treated in this way, and a fair quantity of fume was expelled. One of the conditions necessary for the success of the operation, was that the temperature should be not less than 1600°C. A fair amount of fume came away while the slag was melting. A period of quiescence then intervened, when the fume came off again in large volumes, on the temperature rising to 1600°C. Agitation of the charge helped considerably, but this agitation had to be continuous to be effectual. From assays taken it was found that from 35 % to 40 % of the zinc was expelled.

The cost of working this method was however found prohibitive. A large amount of labor was necessary, and the quantity of fuel consumed in maintaining so high a temperature placed it beyond the possibility of being a commercial success.

The Electric Furnace.

Having met with only a small measure of success, attention was next turned to the advantages offered by the electric furnace. A 350 kw. motor generator set, capable of giving 7000 amp. at 50 volts, had been installed for treating zinc ores electrothermically. A small furnace was built of circular section, lined with 9 in. of English firebrick and holding about 500 lb. of slag. The top was left open so that the progress of fusion could be followed from beginning to end.

Early during the test it was noticed that the action of the slag on the lining was very drastic, and at the end of six hours nothing remained of the furnace but the outer iron shell.

As this was more of a preliminary experiment than an actual test, no figures were taken of power consumption or zinc extraction, though it was observed that dense volumes of fume were evolved.

Numerous other linings were tried including chrome and magnesite, but the experience gained was identical in each case, no refractory material could stand the intense heat and the action of the slag. Finally recourse was had to a water-jacketed furnace. A tank was therefore constructed, of trough form, 14 ft. long and 2 ft. wide, having a two-course brick lining, the idea being to have a furnace in which the molten slag would be kept in a state of flow, thereby endeavouring to establish a continuous operation.

Four electrodes were introduced at equal intervals through the roof, the carbon tamping in the hearth making the negative side. Cold slag was fed at one end, and, on fusing, travelled to the other end of the trough, having to pass three intensely hot zones on its way to the tap hole. Continuous charging and tapping were maintained with excellent results, a large tonnage being treated with an extraction of 60 % of the zinc in the slag.

When the furnace was dismantled it was found that in the space formed, due to expansion, between the inner and outer lining of bricks, about half-a-pound of metallic zinc had condensed. This led to the conclusion that, under suitable conditions, it should be possible to condense the fume by the same operation, and thus save the additional cost of retorting.

In order to collect the fume a new furnace was built, consisting of two concentric rings of boiler plate having a 3-in. water space between. A set of flues, connecting to a fan and bag house, was erected and 10 tons of oxide collected. In appearance the oxide was somewhat grey, though occasionally there would be periods when the product from the bags would be nearly white. The carbon contents explains the difference in the colour, but no reason can be assigned as to why it should be more prevalent at some periods than at others. The oxide produced by the above method, it was observed, was of greater density than that recovered by the blast-furnace process of extraction mentioned later; it would be reasonable, however, to expect a good deal more occluded air in blast-furnace oxide than in that produced electrothermically.

The following is an analysis of the electric-furnace oxide :—

	%
$PbSO_4$	15.12
$PbCO_3$	5.00
ZnO	62.8
Fe_2O_3	.7
Al_2O_3	2.21
SiO_2	4.07
C	.93
CaO	tr.
As	tr.

In all cases a resistance type of furnace was used, this giving the highest efficiency.

Besides using cold dump slag several tests were made on hot slag direct from the blast furnace, as it was considered that by utilising the heat already in the slag a great saving in power could be effected. The contrary was, however, found to be the case, as shorter time is required to remove the zinc from cold slag, than when using it hot.

Reducing agents and fluxes were discarded, as no advantage could be found to result from their use.

There is no doubt that given cheap power and a moderate price for graphite electrodes, the extraction of zinc from lead blast-furnace slags of low zinc contents could be looked upon as a commercial possibility, those usually run and experimented upon at the works containing about 9 % Zn.

The Slag-Eye Furnace.

After a lapse of some three years, the question was again brought to the fore, and after careful consideration a small blast furnace was constructed.

Two rows of tuyeres were allowed for, 15 in. apart, with the bottom row 9 in. above the bottom of the furnace, the area at this point being 4 ft. 6 in. x 2 ft. 3 in. The depth of shaft from tap hole to feed floor was 9 ft. 3 in., while above the feed floor a large chamber was built for the cooling of the gases before passing to the flues leading to the bag house. The original tuyeres, 3 in. diam., were found to be too large, therefore cast-iron thimbles were used to reduce the size to 1⅜ in. diam.

Soon after starting it was found that the two rows of tuyeres were rather a disadvantage, a careful balance in the blast pressure having to be maintained, otherwise a back draught was produced in the top row, which quickly destroyed the sleeves on the bustle pipe. At the same time an element of risk was run by the men attending the furnace when they opened the tuyeres, as a consequence the top row was discarded. A 5-ft. charge column was found to give the best results when working with a blast of 8 to 10 oz. By these means it was possible to run the furnace with a hot top, while at the same time a minimum amount of dust was blown into the flues.

From the cooling chamber the fume was carried along 30 ft. of brick flue and 180 ft. of 40-in. diam. iron pipe to a Fichter fume-collecting plant, and from thence to the bag house. The Fichter plant, owing to the poor condition of some of the elements, on account of their having been idle for some years, did not collect much fume, but it answered the purpose of a cooler, the gases being so hot that the original arrangement, whereby the fume went straight to the bag house, did not allow sufficient length of pipe and in consequence many of the bags were destroyed.

The bag house consisted of five rows of 12 bags, each 18 in. diam. and 17 ft. long. Two qualities were used, unbleached calico and grey flannel, the latter having the longer life. A by-pass was introduced between the furnace and the bag house, by which means it was possible to divert the fume to the smelter stack, in the event of the bags requiring repairs or renewals. At the same time, as the capacity of the fan in use was not large enough to take all the fume, it was possible to run the furnace at full capacity, likewise preventing any fume from blowing through the charging doors, and interfering with the feeding.

In order to thoroughly test the method, three distinct charges were used: slag briquettes, slag nodules, and ordinary dump slag.

The first to be used were the briquettes having the following composition:—

Crushed slag	−⅛-in. size	100 parts
Limestone	,,	15 ,,
Coke	,,	15 ,,
Cement		1.5 ,,

From the outset a great deal of trouble was experienced, through the friable nature of the briquettes, which broke up in the furnace and filled the crucible and tuyeres with fines. It was also found necessary to add an additional 26 % of coke, part of which went up to make up for the amount of fine coke blown out of the furnace. Quite apart from these mechanical troubles however, the cost of making briquettes was found to be too high to ensure a profitable undertaking.

In dealing with the slag nodules, all the above-mentioned objections also applied, but in spite of the many difficulties encountered, some valuable data were collected.

The assay of the charge gave—lead, 3.6 %; zinc, 7.8 %. The zinc is on the low side which is, of course, due to the dilution of the slag by the fluxes. The slag tapped ran on an average .5 % lead and 3.2 % zinc. The recovery calculated on these figures being 70 % lead and 60 % zinc. The high lead contents of the slag is accounted for by the fact that it was taken from an old section of the dump.

During all the operations a great deal of trouble was experienced through the formation of sows, but by building the crucible with a slope in the direction of the tap hole, this trouble was overcome.

The treatment of the nodules was a replica of the briquette campaign, only of shorter duration, giving practically the same results.

Following the briquettes and nodules, a trial was carried out with slag direct from the dump. A certain proportion of limestone was added in order to run a slag going about 25 % CaO.

The following is the composition of the average charge :—

Slag	..	100 parts	..	1 in.
Limestone	..	17 ,,	..	1 ,,
Coke	..	34 ,,	..	3 ,,

carrying 2.3 % Pb. and 9.8 % Zn. The tapped slag went 1 % Pb. and 5.4 % Zn. The recovery on these figures gives 60 % Pb. and 41 % Zn. These results are low, but from data obtained while using a small quantity of slag rich in zinc, it was found possible to maintain a recovery of about 75 % and it was also found to be a comparatively simple matter to reduce the zinc to about 5 %, regardless as to whether the original contents were 9 % or 15 % so that, in running on a slag going 15 % or 20 % Zn., a fair margin of profit would be shown.

About 40 tons of oxide of a blue-grey colour were collected which, on ignition, appeared creamy-white and gave the following analysis :—

	%
PbO	25.42
ZnO	63.00
CaO	tr.
Insol.	.70
So_3	8.00
Sb_2O_3	.13
As_2O_3	.85
Fe_2O_3	.28
CuO	tr.
Cl	.014

CONCLUSIONS.

From these tests certain definite data were established, showing that, in order to successfully recover zinc from lead blast furnace slags, the zinc in the original slag should not be much below 15 %.

In addition it was found that a large proportion of the zinc is evolved during the process of melting, hence cold slag is preferable to slag in the molted state to commence with.

The slag having reached the molten stage no more fume comes off until the temperature attains the region of 1600° C. or over. A lower temperature can be used, say 1200° C., provided the bath is kept in a state of constant agitation during the whole period of treatment.

The above points concerning critical temperature were established through the medium of the electric furnace, which proved particularly suitable for this class of work, where a condition was required at all times that would permit of a close and constant watch being kept on the operations as a whole, but more particularly on the bath of slag itself.

In order to carry the experiments through to a finality a small electrolytic zinc plant was erected for the treatment of the oxide. The plant was capable of producing about one ton of zinc per day and the whole of the oxide was converted to metal, which presented no difficulties in operating beyond those usually encountered in converting oxide to metal electrolytically, a high-grade zinc being produced.

SULPHURIC ACID: THE CHAMBER PROCESS UNDER TROPICAL CONDITIONS.

BY W. H. MAWDSLEY.

THOUGH the literature on the chamber process is considerable, it mostly refers to European conditions. Owing to the demand for acid for flotation and leaching at the mine, it may be necessary to work the process under other conditions. Consequently, some results obtained during the chlorination days at Mount Morgan, within the Tropic of Capricorn, may be useful for reference when working in a similar climate.

Though the chambers must be protected against tropical storms, thorough ventilation should be provided, with plenty of space between the chambers, which are almost invariably crowded together. Not only does the space assist in the cooling of the chambers, but it is very desirable during repairs, when lead and timber have to be hoisted up.

The connecting flues between the chambers, which are fairly efficient mixers and condensers, should be round, supported from above, and with the least possible timber about them. Their position and arrangement deserve careful attention.

Lattice work will be sufficient protection for the sides of the chambers, and the roof should be high and well ventilated.

The Mount Morgan plant, crowded and not well situated, consisted of seven chambers (four over 50 ft. in length), one Glover tower 7 ft. 2 in sq. x 20 ft. high, one Gay Lussac 9 ft. sq. x 30 ft. high, also one 5 ft. diam. x 25 ft. high. There was one pipe column 4 ft. sq. x 14 ft. 6 in. high.

The chambers were run as one unit, and were much lower than those usually constructed in Europe—less than 15 ft. high. Provided that suitable timber can be obtained, 20 ft. is quite low enough. It should be quite satisfactory to use round poles for the studs, and so admit of more air space between studs and lead.

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FURNACES.

These comprise one continuous brimstone burner and four pyrites kilns, each burning about a ton of ore daily. The ore from the mine, contained about 36 % S. It burned well, the cinders averaging about 3 %, and giving no dust trouble; with labour-saving appliances the writer is of opinion that lump burners are worth considering. They delivered the gas through a water-cooled iron flue direct to leading chamber. The nitre-potting arrangement was attached, so that no nitre went into the Glover, to which the brimstone burner was connected. The draught was obtained from a chimney, to which the boiler supplying steam was connected. For some months a motor-driven fan was used. One night an explosion announced that a good deal of it was missing, evidently owing to an excess of centrifugal force. Luckily, there were no casualties. In some chambers water sprays were used, and were quite satisfactory.

The chamber capacities were :—

	cub. ft.
	11,733
	23,842
	12,660
	15,112
	26,000
	18,696
	11,600
Total ..	119,643
Towers and connecting flues ..	4,577
Total ..	124,240

ACTION OF ACID ON THE LEAD.

Where the sides of the chamber in the "tray" are exposed to the action of acid on both sides, and where, owing to vertical position, lead sulphate cannot accumulate, the wear of the lead is most severe.

In order to ascertain the extent of the action, strips of sheet lead were cut to uniform weight and carefully marked. A hole near the top of each strip allowed of their being suspended in the acid without contact with the chamber lead. Strips of English and Australian lead were suspended side by side in each chamber, and were taken out, washed, dried, and weighed at the end of each month. Sometimes there was a slight increase in weight. Both brands of lead were of the best chemical quality, and the analysis was supplied by the makers. Below are given the respective weights :—

Loss in Weight of Strips of Lead, about 9 *in.* x 1 *in., Suspended in Chambers for Three Years. Original Weight,* 228 *grm.*

—	No. of Chamber.						
	1.	2	3.	4.	5.	6.	7.
Loss in weight—(A)	50.8	51.0	26.3	138.5	126.0	47.1	30.8
(B)	45.8	32.9	44.2	151.8	100.2	38.6	33.8
Average Tw of Acid	120°	121°	115°	128°	107°	114°	115°
Temperature of acid—							
Summer ..	33°	—	30°	32°	30°	29°	—
Winter ..	28°	25°	24°	26°	—	25°	27°
No. of weeks chamber idle	15	32	35	10	28	3	80

Loss in Weight per annum, grm. :—

	1		2		3		4		5		6		7	.
A	18.0	7.9	23.0	10.0	11.3	5.0	49.3	21.6	51.1	22.4	16.0	7.0	21.0	9.2
B	16.8	7.3	13.8	6	19.0	8.3	54.0	23.6	47.0	17.8	13.1	5.7	23.1	10.1

Total loss in three years, without allowing for time chambers were out of commission—A, 29.49 % ; B, 27.72 %.

The make of acid was determined weekly, as well as at the end of each month, and the writer believes that the density of the chamber acid was from the weekly average.

In some cases the surface of the lead became rough, like very coarse sand-paper ; in others there were vertical grooves eaten in. Sometimes, too, round holes rather larger than a pin's head, filled with sulphate, penetrated just below the surface of the lead. Occasionally the writer has known lead to wear uniformly thin and smooth, becoming very flexible, but usually it has been deeply grooved and pitted and decidedly hard. This grooving seems to point to a segregation of the impurities. Allowing for the presence of 0.02 % Zn in the lead, in one ton there would be

44.8 lb., and the question of how this is spread over 373 sq. ft. (6 lb. or 320 sq. ft ; 7 lb. = 1 ton) would considerably affect its resistance to acid. The analysis is of little use in this direction.

PIPE COLUMN.

This is claimed to economize space, but is rather costly to construct. Results obtained may be of interest :—

Size.—4 ft. x 4 ft. x 16 ft. high, containing 8 rows of pipes 2½ in. outside diam., 8 in each row, and 7 rows with 7 in each ; total, 113 pipes 4 ft. long, weighing 38 cwt.

Capacity.—232 cub. ft., less 15.4 cub. ft. space occupied by pipes = 216 cub. ft.

Surface Area.—Sides, top, and bottom	..	264 sq. ft.
Area of pipes ..	..	295 ,, ,,
		559 ,, ,,

The surface area is thus considerably more in proportion to its capacity than with an ordinary chamber.

SITUATION.

The chambers were so crowded together that the only space available was at the back of No. 3 chamber. The acid condensed was collected in a small tank and measured, so that the "make" of acid could be determined. During one week in June, when rather more than 19 tons of brimstone were burnt, the "make" of the chambers and pipe column was carefully estimated. At this time there were 5 chambers in use, and the *daily* "make" was :—

Chamber.	Capacity, cub. ft.	Cwt. of acid, 123°	Cub. ft. per cwt. of acid.	Sq. ft. of surface, per cwt. of acid.
1	11,600	34	341	98
*2	19,733	62	318	91
3	26,000	80	325	89
Pipe Column	216	4¼	50	131
*4	27,000	46	586	157
5	11,733	3½	3352	957

* These two chambers, subsequently renewed, were reduced to 18,696 and and 23,842 cub. ft.

These results show that, though the pipe column required only 50 cub. ft. for 1 cwt. 123° acid daily, the lead area per cwt. is much more than in the first three chambers.

Condensation in lead connecting flue between pipe column and No. 4 chamber (116 ft. 8 in. long x 1 ft. 2 in. sq.)—Area of lead, 544 sq. ft.; capacity, 158.7 cub. ft.; average make during 14 days in October, 2.54 cwt. acid 123°; cub. ft. per cwt. daily, 62.48; sq. ft. surface per cwt., 214.

This shows better results than the chamber, but inferior to the pipe column. The proportion of surface to capacity deserves careful attention.

LUTING A CHAMBER WITH WATER.

This is very undesirable, but on one occasion had to be done in summer with a small chamber, the last in a series. In 18 days there was an increase of ¼ in. in depth, and the density became 74° Tw.

CHAMBER CONDITIONS IN APRIL (Winter).

Chamber space between 11 and 12 cub. ft. per lb. of S daily.

	SO_2.	O.
Brimstone gas average—	9.80 %	9.40 %
Pyrites ,, ,, —	7.50 %	8.00 %

Chamber exit 8.00 % O and 2.5 gr. SO_3 per cub. ft.

Speed of Gay Lussac exit, about 7 ft. per sec.

Brimstone burnt, about 2½ tons daily.

Pyrites burnt, about 3½ tons daily (33 % available S).

Total S for month, 99 tons 16 cwt.

Acid made, 364 tons 18 cwt. (123° Tw)

Yield of acid on sulphur burnt, 91.40 %.

Nitre, 6.4 %.

——	1.	2.	3.	4.	5.	6.	7.
Temperature of chambers, 11.30 a.m. ..	70°	62°	40°	61°	—	38°	36°
Temperature of chamber acid	32°	28°	26°	30°	—	28°	29°
Density of chamber acid Tw	129°	117°	118°	*135°	—	120°	117°

* Abnormally strong.

Temperature of atmosphere, 11.30 a.m., 26°.

Temperature of Gay Lussac exit, 11.30 a.m., 31°. Bar 29.4″.

Chamber Conditions in November (Summer).

Two chambers idle and 2 pyrites furnaces out.

—	1.	2.	3.	4.	5.	6.	7.
Temperature of chambers, 11.30 a.m. ..	74°	—	57°	68°	48°	39°	—
Temperature of chamber acid	33°	—	30°	32°	30°	29°	—
Density of chamber acid Tw	114°	—	119°	127°	112°	118°	—

Temperature of atmosphere, 11.30 a.m., 29°.

Temperature of Gay Lussac exit, 11.30 a.m., 37°. Bar. 29.4″.

Chamber space (62,152 cub. ft.), 9.5 cub. ft. per lb. of S.

SO_2. O.

Brimstone gas average—10.9 8.8

Pyrites ,, ,, — 8.5 7.8

Chamber exit—10.26 % O and 3.30 gr. SO_3 per cub. ft.

Speed of Gay Lussac exit, about 8½ ft. per sec.

Brimstone burnt, about 2½ tons; pyrites, 1½ tons (33 %) daily.

Total S for month, 88 tons 17 cwt. 2 qr.; nitre, 8.20 %.

Acid made, 308 tons.

Yield of acid on sulphur burnt, 86.60 %.

In June (midwinter), when the brimstone furnace was idle for 12 days, the temperatures were :—

—	1.	2.	3.	4.	5.	6.	7.
Temperature of chamber, 11.30 a.m. ..	60°	47°	26°	56°	—	30°	27°
Temperature of chamber acid	22.6°	19°	18°	23°	—	19°	21°
Density of chamber acid Tw	124°	110°	112°	120°	—	113°	117°

Temperature of atmosphere, 11.30 a.m., 19°.

Temperature of Gay Lussac exit, 11.30 a.m., 24.3°; No. 1 pyrites furnace pipe, 92° to 147°. Bar, 29.4″.

The "creeping" of lead, especially vertically, is one of the troubles in a chamber plant. The lead being made fast on top, the downward movement tends to draw it out and make it thinner about the crown plate. To provide against this, the sheets are sometimes rolled thicker for about 2 ft. from the end. The "creep" is sometimes to the extent of 3 in. or so, and the horizontal straps often tear off or give way. Some provision might be made to allow for the horizontal rails being lowered, after the creeping had begun, sufficiently to support the lead without undue strain on the straps. It should also be worth while having the ends of the sheets thicker where immersed in the acid, that being usually the first place to need patching.

Owing to the acid being in layers of varied density in a chamber, there is some little trouble in getting a fair sample. The writer got good results with a copper cylinder open at one end and with lugs at the side near the top for a handle, similar in style to that of a bucket. There was a series of holes bored vertically in one row from bottom upwards. A pipe, open at both ends, fitted neatly inside, with holes bored to correspond with those in the cylinder. A projecting lug at the top of the pipe fitted in a recess in the top of the cylinder, allowing for a lateral movement of the pipe; consequently, by immersing the cylinder with holes blocked, and then moving the inside pipe till the holes corresponded, acid came in at various levels at the same time; then, by reversing the movement, the cylinder retained the acid, which could be emptied into a jug. Having occasion once to empty a small chamber into tanks, the writer found that, though the densities varied, the total agreed closely with that calculated to be in the chamber.

Estimation of quantities of acid is usually done by working out factors for the various chambers and tanks—*e.g.*, chamber 100 x 30 = 3000 sq. ft.; at a depth of 1 ft. would contain 3000 cub. ft., and at a depth of 1 in. 250 cub. ft. The tables in use generally give lb. of acid per cub. ft.—*e.g.*, 1 cub. ft. at 110° contains 86.62 lb. acid at 123°. To get the quantity in tons, the result must be divided by 2240; for this reason the 250 as above is divided by 2240 = 0.112, which may be called the factor for that chamber. Now, 0.112 x 86.62 = 9.70, or the number of tons of acid at 123° for every inch in depth. Consequently, by ruling a book and entering up the various densities as they occur it only becomes necessary to look up the factor for the density found multiply by number of inches, and the result is obtained in tons at 123°.

In order to simplify this work it is advisable to have the tanks and chambers as relatively uniform as possible.

A DESCRIPTION OF THE TREATMENT OF THE COPPER IMPURITY IN THE LEAD ORES SMELTED AT THE SULPHIDE CORPORATION'S WORKS, COCKLE CREEK.

By D. C. M'Gruer.

THE question of dealing with the small quantities of copper found in a great many of the purchased ores became a factor of importance when the Sulphide Corporation decided to refine its own lead bullion, as the presence of this impurity has a marked effect on the efficiency of the de-silverizing operations of the Parkes process.

Removal of the Copper from the Base Bullion.

The copper is removed from the base bullion by drossing, which collects the copper, and at the same time has considerable gold, silver, and lead values. The drossing of the bullion is done in two stages—firstly, at the smelters; and secondly, in the copper kettles at the refinery. In both cases a "wet" dross is produced, which is subsequently "sweated" in a suitable type of furnace. When "dry," the dross is raked out and stored until enough accumulates to warrant a run on dross in the small blast furnace kept for that purpose.

A typical assay of the "dry" dross is as follows:—

Au	.3 oz. per ton.
Ag	55 ,, ,, ,,
Pb	60–70 %.
Cu	6.5 %.
Fe	2.2 %.
Zn	1.5 %.
Sb	4.5 %.
As	1.6 %.
S	4.5 %.

Working the Dross up to Low-Grade Cu–Pb Matte.

The accumulated dross is treated in a small blast furnace with the necessary fluxes, producing a low-grade Cu–Pb matte and base lead bullion.

[This paper is separately bound, and may be, if so desired, detached complete from this number.]

The assay value of the matte being approximately as follows :—

Au	.05 oz. per ton.
Ag	30.0 ,, ,, ,,
Pb	23.2 %.
Cu	23–25 %.
Fe	25 %.
Zn	3.0 %.
Sb	5.6 %.
As	3.3 %.
S	14.4 %.

Treatment of the Low-Grade Cu–Pb Matte.

This matte was formerly crushed, roasted, then leached with H_2SO_4 and copper precipitates produced; but owing to the shortage of scrap iron some other means of converting the Cu into a marketable form had to be sought.

The conversion to bluestone showed most promise, and with this object in view the low-grade matte is crushed through ¼-in. screen, given a quick roast in the rotary furnaces, then over a Dwight--Lloyd machine, and finally worked up to high-grade matte in a reverberatory furnace.

In working the low-grade up to high-grade matte, the time of treatment is gauged by the Fe contents of the charge, and when a dip sample shows the Fe to be about 2 % the charge is tapped, irrespective of the copper values.

The lead loss is naturally high, but provision is being made to connect the reverberatory furnace to a bag house in the near future.

An average assay of the high-grade matte produced is as follows :—

Au	1.125 oz. per ton.
Ag	69.0 ,, ,, ,,
Pb	24.0 %.
Cu	47.0 %.
Fe	2.0 %.
Zn	2.4 %.
S	17.0 %.

The high-grade matte is crushed in a Krupp mill through 1/40-mesh screen, roasted in a 4-hearth hand reverberatory furnace, and then passed on to the leaching department for the production of bluestone. The temperature aimed at when roasting is between 600° and 625° C., the following tests being taken under working conditions :—

No. 1 hearth ..	460° C.
No. 2 ,, ..	532° C.
No. 3 ,, ..	582° C.
No. 4 ,, ..	618° C.

An average sulphur assay of the roasted product is as follows :—

Total S	7.7 %.
S as SO_3	7.4 %.

Bluestone Department.

Working Up the Cu in the Roasted High-Grade Matte to Bluestone.

The copper is dissolved out of the matte by leaching with dilute H_2SO_4 in an ordinary circular agitation vat provided with a wooden paddle, which is driven by a spur and pinion wheel fitted over the top of the vat.

Two such agitators are in use, and they are used for either leaching the roasted matte or purifying the neutral leach liquors. Sometimes one is treating matte and the other is purifying liquors, and at other times they are both purifying accumulated neutral liquors. The production of a neutral impure liquor occupies from 1 to 5 hours, whereas 5 to 15 hours are necessary for purification, according to the quantity of iron present; therefore an accumulation of impure neutral liquor takes place.

In making up neutral liquors, the roasted high-grade matte is carefully weighed, then tipped into the agitator, which has been previously filled to the correct level with H_2O (or acid wash liquors from a previous charge) and a calculated quantity of H_2SO_4.

Sufficient acid is added to give a neutral liquor containing 70 to 80 grm. per litre of copper.

The temperature of the liquor is kept up to about 70° C. by means of live steam delivered to the bottom of the agitator.

Samples are taken during the agitation, and a test made for Cu, Fe, and free H_2SO_4.

When the copper in the solution is correct, and the acid neutralized, the agitation is stopped, steam turned off, and the pulp allowed to settle, the clear liquor then being syphoned off to the storage vat for impure neutral liquors. It has been found that at least three leaches can be made before it is necessary to discharge any residues. The Cu contents of the matte, of course, control the size of the charge to agitators, and consequently the number of charges treated before discharging a residue.

TREATMENT OF THE RESIDUES IN AGITATOR.

After the third neutral liquor has been syphoned off, two successive acid washes are given to the residues. Each wash is given about 2 hours' agitation with 5 to 10 % H_2SO_4. Live steam is used to raise the temperature to about 60° C. Periodical tests of the wash liquor for Cu and acid are taken, and, when no further increase of Cu in the solution is shown, the agitation is stopped, the pulp allowed to settle, and the clear acid-wash liquor is run off to the wash-water storage vat. From the vat it is subsequently pumped back to the agitator for the next charge to make up neutral leach liquors of the required strength. After the second acid wash has been settled and run off, sufficient water is added to flush the whole of the residues out of the agitator through a bottom discharge into No. 1 of three cone-shaped settling vats, which are terraced to flow from No. 1 to No. 2, and so on, finally overflowing into the storage vat for acid-wash liquors. These vats allow the pulp to settle, and the clear wash water, which contains a little copper, is either displaced by running in fresh water to No. 1 or by syphoning off to the acid-wash storage vat. The thickened pulp is discharged through a bottom discharge pipe into a large brick bin, where it is allowed to dry out sufficiently to be sent to the roasting department. All bluestone plant residues, which represent about 40 % by weight of the original high-grade matte leached, are incorporated in the H.H. pot charge, which forms part of the ordinary daily charge to the blast furnace.

Of the metal values in the high-grade matte treated, all of the Au, Ag, and Pb is retained in the residues, together with—

%	
46	of the Fe.
32	,, ,, Zn.
9.5	,, ,, Cu.

The Au, Ag, and Pb values are thus separated from 90.5 % of the copper, and are subsequently recovered with the bullion produced in the blast furnace, the Cu that escaped solution being again drossed off.

Purification of the Impure Liquors.

Iron is the chief removable impurity, and during its precipitation the whole of the As and Sb is also precipitated.

The Hofmann system of purification has been successfully employed. This system claims that in the presence of air and CuO (in hot liquors) ferric sulphate is oxidized, then precipitated as ferric oxide, and that a chemical equivalent of copper goes into solution as $CuSO_4$. A considerable departure from the somewhat elaborate purifier, as described by Hofmann, has been made, and all liquor purifications are carried out in an ordinary agitation vat.

Several methods of applying the air have been tried, but the best results have been obtained by delivering the air and steam at a point near the bottom of the agitator, either by two independent lead pipes of equal length strapped together—one for air and the other for steam—or by mixing the air and steam in one lead pipe. Whichever method is applied, the Pb pipe is securely fixed to the inside of the agitator by means of wooden cleats.

Procedure for Purifying Liquors.

The agitator is filled to the correct level with impure neutral leach solution. A sample of the liquor is taken and tested for iron in the ferrous state, the agitator is then started, and steam and air turned on. For the necessary CuO either ordinary roasted high-grade matte or roasted copper precipitates are used, and, as the temperature rises in the agitator, about 300 lb. of roasted matte or precipitates are tipped in.

The progress of the purification is carefully watched by means of a sample of the liquor taken every hour, and a test made for ferrous iron by acidifying the sample with H_2SO_4 and titrating direct with standard $KMnO_4$. In the presence of the added CuO (in the roasted matte or precipitates) no appreciable iron in the ferric state is found in the solution; therefore a titration for Fe in the ferrous state gives a true working indication of the total iron in the solution at any stage of the purification.

The amount of Fe in the impure neutral liquors varies considerably, according to the iron in the matte treated and the completeness of the roasting. The maximum Fe found in the impure leach liquors is about 10 g.p.l. (grammes per litre), and the minimum about 2.0 to 2.5 g.p.l.

The degree of purification aimed at is from .15 to .2 g.p.l. Fe. From 5 to 15 hours' agitation and aeration are necessary, and, when the purification is finished, the agitator is stopped, steam and air turned off, and the charge allowed to settle. The clear solution is then syphoned off to the storage vat for purified liquors.

The following tabulation shows the completeness of the removal of Fe, As, and Sb, the Zn not being affected :—

	Cu.	Fe.	As.	Sb.	Zn.
Impure liquor (g.p.l.) ..	73	5.1	1.05	trace	3.0
Purified liquor (g.p.l.) ..	80	.15	trace	*nil*	3.1

RESIDUES IN PURIFIER.

After decanting the purified liquor, the residue, which contains a considerable bulk of precipitated ferric oxides, is given a weak acid wash to dissolve the unconverted CuO. About three hours' agitation is given. The residue is allowed to settle, and the liquor decanted to the acid-wash liquor storage vat. If necessary two acid washes are given, then the residues are discharged, with water, in exactly the same manner as ordinary leach residues when making up neutral impure liquors. All acid-wash water is used as subsequent leach solutions for fresh charges of impure liquor.

CONCENTRATION OF THE PURIFIED LIQUOR.

The main evaporating pan is a rectangular lead-lined wooden vat of 750-gal. capacity. The first arrangement consisted of six 4-in. lead-covered boiler tubes let into the vat longitudinally, with a fire-box, suitable for burning coke, at one end, and a chimney at the other. The rate of evaporation proved to be altogether too slow, and the coke consumption was abnormal. Steam coils were then installed, the first being a 1-in. soft-lead piping. The best results have, however, been obtained by using $1\frac{1}{8}$-in. Sb–Pb piping, containing 4 % Sb. On account of the strength of the hard-lead piping the scale can be periodically removed without injury to the coil. An analysis of the scale that forms is as follows :—

	%
Pb	nil.
Cu	28.8
Fe	.4
Zn	.9
Sb	trace
As	.9
Total S	14.5
S as SO_3	14.5

The evaporator will not hold enough concentrated liquor to fill a crystallizing vat, therefore when the liquor in the evaporator has attained a sp. gr. of 1.4 it is run to a storage vat provided with Pb coil, using the waste steam from the evaporator. This storage vat acts as a further concentrator, and also as a means for thoroughly clarifying the liquor before its gravitation to the crystallizers, where it is delivered at from 1.42 to 1.43 sp. gr. and from 80° to 85° C.

CRYSTALLIZERS.

The crystallizing vats in use are made of brick, lined on the sides with 8-lb. sheet lead, and with 10-lb. lead on the bottoms. Dimensions of the vats are 8 ft. x 10 ft. x 2 ft. 9 in. high, and their capacity 1370 gal.

To give the maximum of surface for bluestone crystals to build upon, each vat has 112 sheet-lead strips 8 in. wide and 4 ft. 3 in. long, hung on 4 x 2 hardwood battens, and allowed to extend down into the vat to within about 7 in. of the bottom. When it is desired to fill a crystallizer, all the strips are placed in position; the hot concentrated liquor is gravitated from the storage vat, covered over with hessian, and allowed to cool slowly for from 7 to 9 days. From 2 to 2.5 tons of dried bluestone are made per charge.

Discharging the Crystallizer.

When the crystallizer is to be emptied, the mother liquor is ejected by means of a steam ejector. The crystals are all knocked off the strips and sides on to the bottom of the vat, then shovelled out and delivered to the washer. Thus two products are obtained from the crystallizing vats—

(1) Mother liquor.
(2) Bluestone crystals.

Treatment of the Mother Liquor.

An average analysis of the mother liquor is as follows:—

	g. p. l.
Cu	84.0
Fe	.8 to 2.0
Zn	11.0
Free H_2SO_4	1.8
Sp. gr.	1.26

The original procedure was to further concentrate the mother liquor and produce a second crop of bluestone, but it was found that the resulting crystals were of low grade, which necessitated their being dissolved and re-crystallized. Assay value of the low-grade bluestone thus produced:—

	%
Cu	24.95
$CuSO_4, 5H_2O$	97.5
Fe	.065
Zn	.15

As only a first-class grade of bluestone is being boxed for sale, the necessity of re-dissolving the low-grade bluestone cut the capacity of the plant down to such an extent that some other means of dealing with this product had to be devised. The present practice, which overcomes the production of any low-grade bluestone, is to by-pass, and run over scrap iron, a definite quantity of mother liquor each week, returning the balance to the purified-liquor storage vat. By this means no building up of the Zn (which is the chief impurity) takes place, and a high grade of bluestone only is made.

The Cu precipitates, produced from the mother liquor, which is by-passed, represent about 15 % of the Cu leached from the matte. It is roasted, and returned to the purifier as a source of CuO.

The only bluestone now being re-dissolved is the undersize from the hutch of the washer. This is dissolved in mother liquor in an agitator provided with a paddle and steam coil. The crystals are added to the liquor until a sp. gr. of 1.435 is obtained. The liquor is then run into the crystallizer with ordinary concentrated purified liquors.

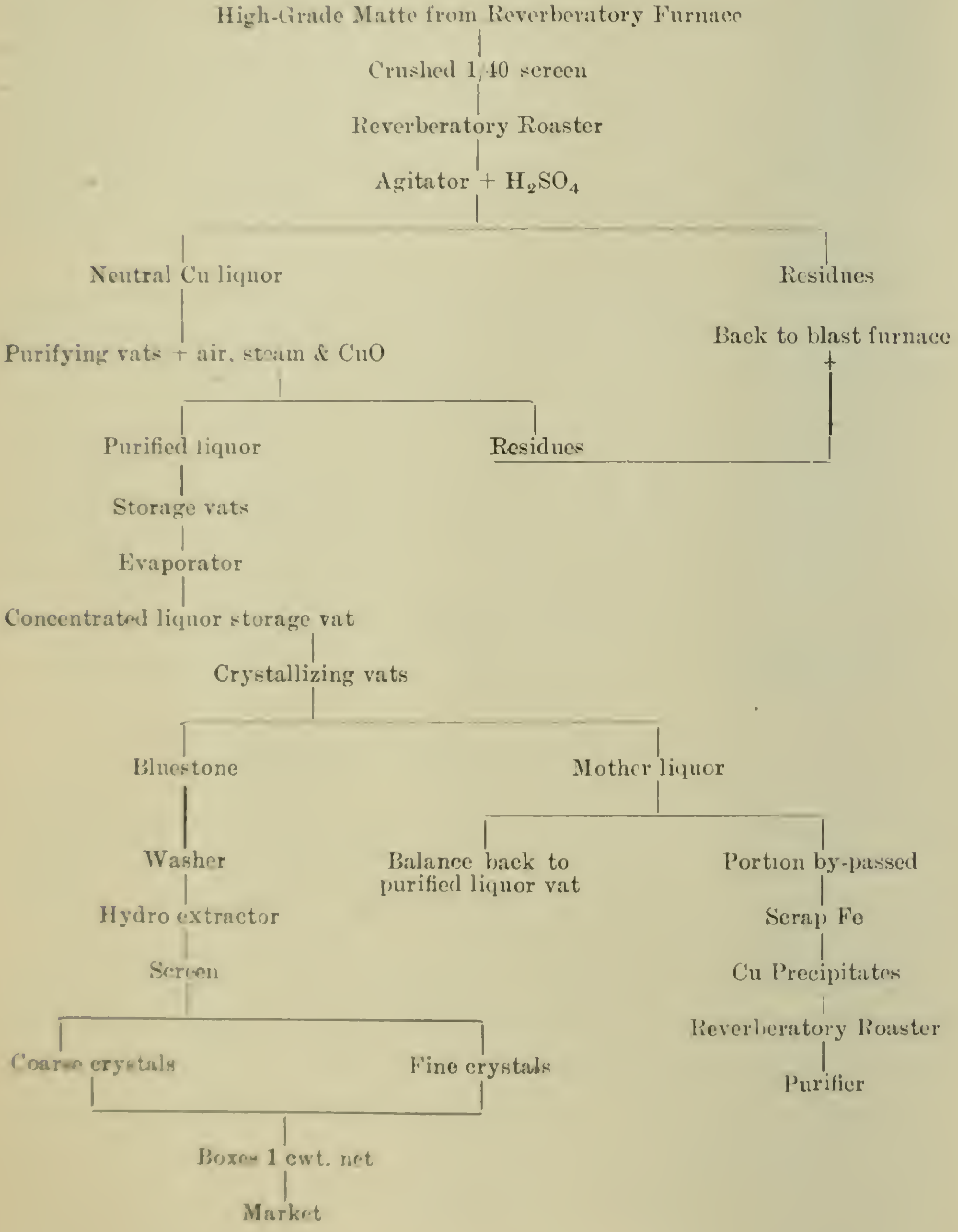
TREATMENT OF THE BLUESTONE.

Washing.—The bluestone, as it comes from the crystallizing vats, has to be washed and freed from any very fine crystals. This is done in a jigger washer, having a fixed screen. Mother liquor is used as the wash liquor.

The screen on the washer has 3/32-in. holes, which allow the undersized crystals to pass through into the hutch; from there they are periodically shovelled and sent to the re-dissolver.

Drying.—The washed crystals are shovelled off the jigger screen into a centrifugal drier, from which they are transferred, when properly dried, to a screen giving two sizes of crystals—¼ in. and + ¼ in.

Boxing the Dry Bluestone.—The boxes used are made of pine, and have an inside dimension of 20 in. x 10 in. x 12 in. Each box is lined with brown paper before being filled, and holds 1 cwt. net of bluestone, of either the coarse or fine grade of crystals, and



Flow-Sheet of Bluestone Plant.

is branded C or F, according to which grade of crystals it contains. Assay value of the finished article is as follows :—

	%
Cu	25.26
$CuSO_4, 5H_2O$	99.23
Ni	.002
Zn	.09
MgO	trace
CaO	trace
$Al_2O_3 + Fe_2O_3$	.07
As	trace
Sb	trace
Se + Te	trace
Nitrates	*nil*
Insoluble	.02

CONCLUSIONS.

It will be noticed that, although about 15 % of the copper leached out of the high-grade matte is by-passed and precipitated on scrap iron, the precipitated Cu is roasted and returned to the purifier; therefore, by the method above described, a metal, which is looked upon as an impurity in Pb smelting, is separated from the Au, Ag, and Pb, and converted into a profitable by-product.

FLOTATION PRACTICE AT MOUNT LYELL.

By L. V. WATERHOUSE, B.E. (Syd.), Member.

THE flotation plant at Mount Lyell was erected, primarily, for the treatment of ore from the Lyell Comstock mine. These workings are situated over a mile in a direct line north of the North Mount Lyell mine, and are connected with the Reduction Works at Queenstown by a 2-ft. gauge steel tramway via the Queen River valley—a distance of 7 miles.

The property was purchased from the Mount Lyell Comstock Copper Co. in 1912. After the disastrous fire in the North Mount Lyell mine in October, 1912, steps were immediately taken to make Lyell Comstock ore available for treatment, in order to relieve distress caused by any prolonged stoppage of work, and subsequently 13,032 tons of ore, averaging 3.38 % copper, 0.28 oz. silver, and 0.034 oz. gold, were smelted.

When operations were resumed at the North Mount Lyell mine, it was evident that there was no economic advantage in smelting Lyell Comstock ore as compared with the higher value North Mount Lyell ore, which was also a better flux for the Mount Lyell pyrites, and that the future of the Lyell Comstock ore depended upon cheap mining and successful concentration of the ore. Therefore, extensive trenching and diamond-drilling was carried out, and a sufficiently large quantity of ore proved available for cheap extraction by open-cut methods. At the same time bulk tests by flotation were carried out at the Minerals Separation testing plant in Melbourne on different classes of ore from the Mount Lyell Comstock mine proper, followed by laboratory tests at Queenstown on all classes of ore available. All these tests demonstrated that the ore was amenable to the process, provided that it was ground finely enough.

Plant erection was delayed by the general dislocation of business at the outbreak of war, but finally it became possible to secure

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all the necessary machinery in Australia and to import motors. Treatment operations commenced on 17th February, 1916, with all the success anticipated. and have since continued..

The sulphides in the Lyell Comstock ore consist of chalcopyrite and pyrites, very finely disseminated through a grey schisty gangue, at times very decomposed. Bands of hard quartzite carrying sulphides also traverse the ore-body.

After operations were well established, trial parcels of North Lyell silicious ore were put through the plant with such success that the mining department made arrangements to select underground in the stopes a lower grade ore than the usual 6 % Cu smelting ore, to supplement the Lyell Comstock milling material, and finally it became possible to start a second shift.

The North Lyell ore carries bornite, chalcopyrite, and pyrites in a silicious gangue, consisting mainly of a very hard quartzite and some schist.

The following are typical analyses of the respective ores :—

	Lyell Comstock.	North Mt. Lyell.
Cu, %	2.6	3.5
Ag, oz.	.23	.7
Au, oz.	.02	.01
SiO_2, %	46.0	66.0
Fe, %	11.5	8.0
$BaSO_4$, %	1.4	2.0
Al_2O_3, %	15.5	7.7

For the year ended 30th September, 1919, concentration results were as follow :—

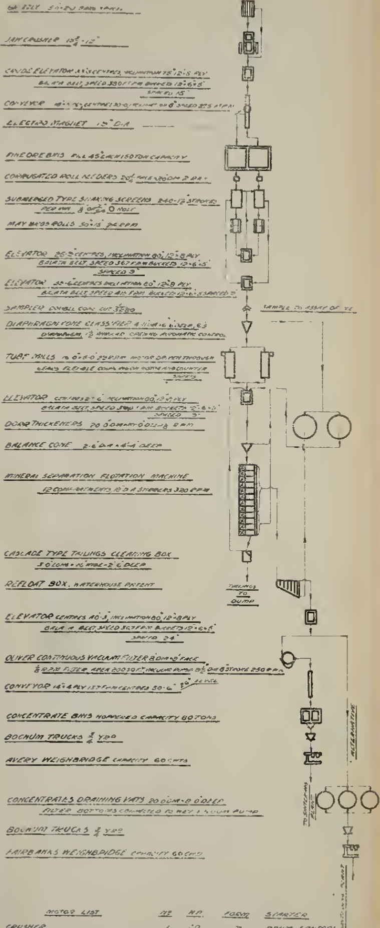
	Tons.	Cu, %.	Ag, oz.	Au, oz.
Lyell Comstock ..	13595	2.18	.2	.028
North Mount Lyell ..	14873	4.74	.88	.008
Total ore	30168	3.43	.54	.018
Concentrates ..	8622	10.95	1.47	.047
Recovery	—	90.41	77.79	72.41

GENERAL DESIGN.

The plant was erected on the old No. 1 smelting plant site, which was convenient for labour, transport, repairs, supervision, etc., and designed to utilize existing facilities to the fullest advantage. These were mainly the old bin framework, connected with railway lines on the main smelter-bin level, in which a suitable crude-ore

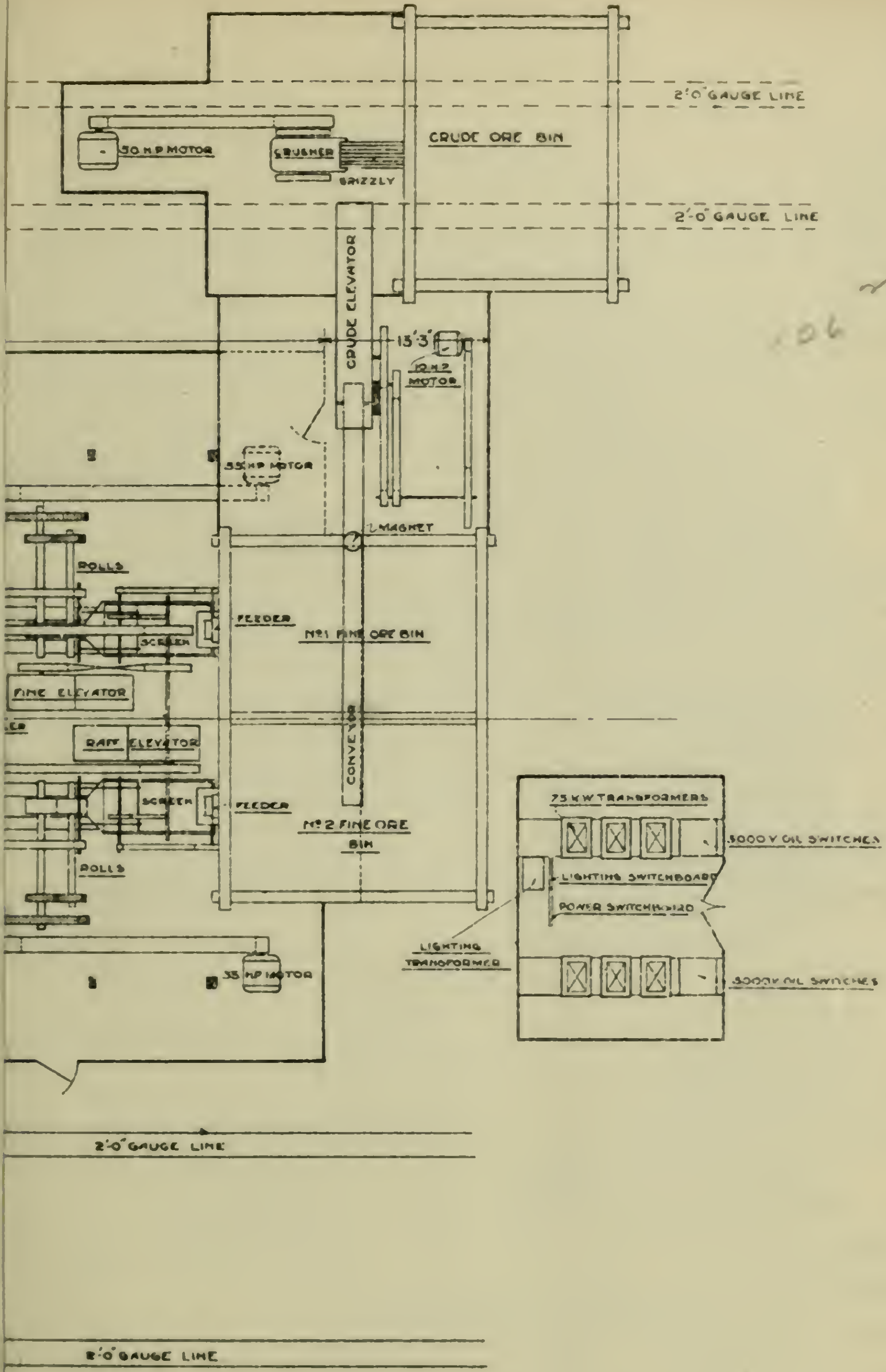
WATERHOUSE—ON FLOTATION PRACTICE AT MOUNT LYELL. PLATE I.

WATERHOUSE—ON FLOTATION PRACTICE AT MOUNT LYELL. PLATE I.

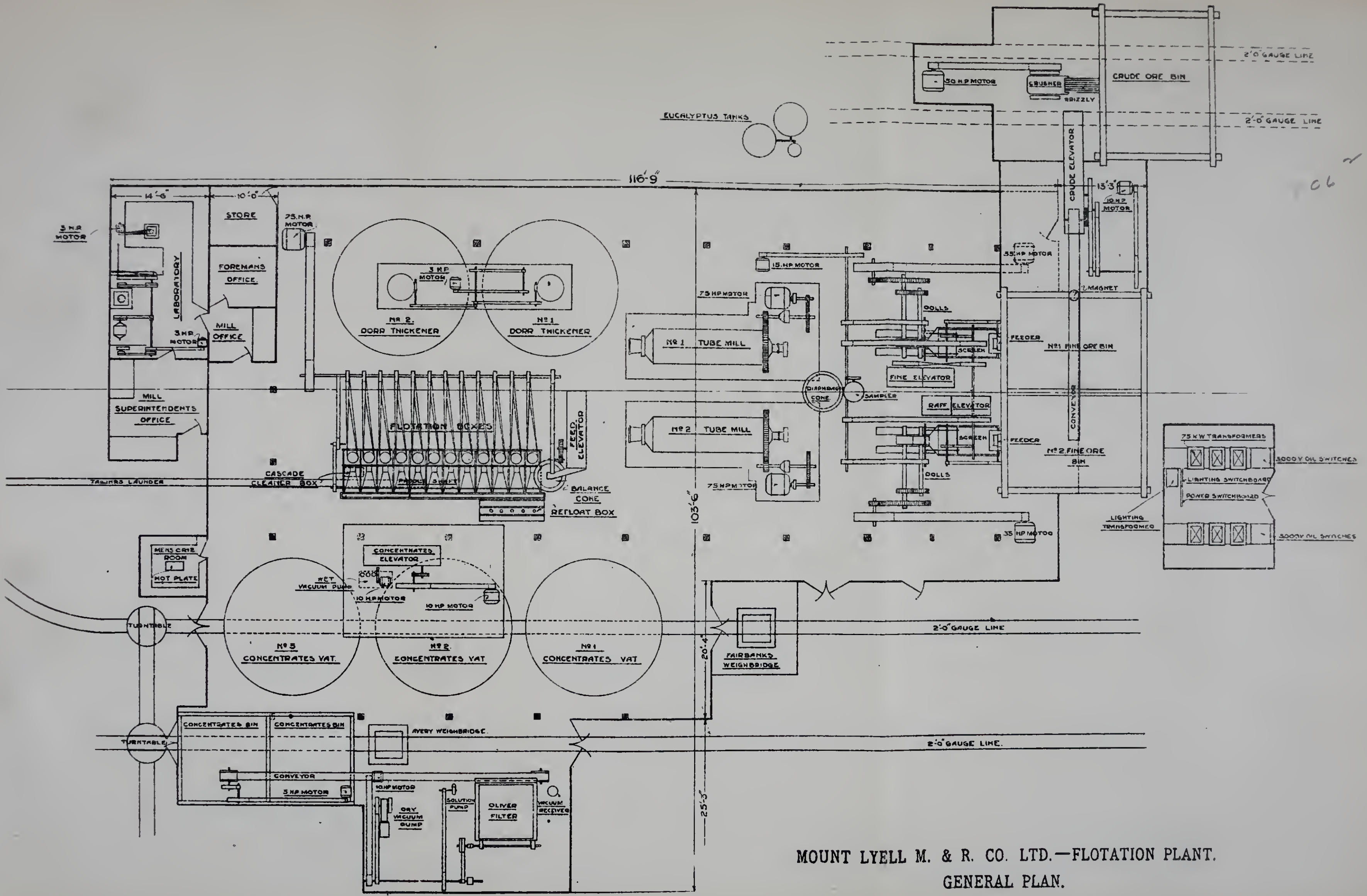

ORE BIN [illegible] ORE FROM [illegible] AND NORTH LYELL MINES. 3½" GRILL
GRIZZLY 5'0"×2'0" BARS [illegible]
JAW CRUSHER 15¾"×12"
CRUDE ELEVATOR 41'3" CENTRES, INCLINATION 75° 12"×5 PLY BALATA BELT, SPEED 330 FT PER MIN BUCKETS 12"×6"×5" SPACED 15"
CONVEYOR 16"×4 PLY CENTRES 30'0" [illegible] ON 6° SPEED 275 F.P.M.
ELECTRO MAGNET 15" DIA
FINE ORE BINS FALL 45° EACH 150 TON CAPACITY
CORRUGATED ROLL FEEDERS 20¼" DIA × 20" LONG 2 RPM
SUBMERGED TYPE SHAKING SCREENS 240-1⅞" STROKES PER MIN ⅜" OR 5/16" O HOLE
MAY BROS ROLLS 30"×15" 96 RPM
ELEVATOR 25'3" CENTRES, INCLINATION 60°, 12"×8 PLY BALATA BELT, SPEED 367 F.P.M. BUCKETS 12"×6"×5" SPACED 9"
ELEVATOR 35'6" CENTRES INCLINATION 60° 12"×8 PLY BALATA BELT, SPEED 415 F.P.M. BUCKETS 12"×6"×5" SPACED 9"
SAMPLER CAMPBELL CON. CUT 1/280
SAMPLE TO ASSAY OFFICE
DIAPHRAGM CONE CLASSIFIER 4'6" DIA × 6'0" DEEP, 6'3" DIAPHRAGM, 1½" RUBBER OPENING AUTOMATIC CONTROL
TUBE MILLS 16'0"×5'0" 23 R.P.M. MOTOR DRIVEN THROUGH GEARS FLEXIBLE COUPLING WITH MAIN AND COUNTER SHAFTS
ELEVATOR CENTRES 27'6" INCLINATION 60° 12"×8 PLY BALATA BELT, SPEED 390 F.P.M. BUCKETS 12"×6"×5" SPACED 9"
DORR THICKENERS 70'0" DIAM × 10'0" DEEP ⅛ RPM
BALANCE CONE 2'6" DIA × 4'4" DEEP
MINERAL SEPARATION FLOTATION MACHINE
12 COMPARTMENTS, 18" DIA STIRRERS 320 RPM
CASCADE TYPE TAILINGS CLEANING BOX
5'0" LONG × 16" WIDE × 2'6" DEEP
REFLOAT BOX. WATERHOUSE PATENT
TAILINGS TO DUMP
ELEVATOR CENTRES 40'3", INCLINATION 60°, 12"×8 PLY BALATA BELT, SPEED 367 F.P.M. BUCKETS 12"×6"×5" SPACED 24"
OLIVER CONTINUOUS VACUUM FILTER 8' DIA × 8' FACE
⅛ R.P.M. FILTER AREA 200 SQ FT VACUUM PUMP 9½" DIA 8" STROKE 250 RPM
CONVEYOR 14"×4 PLY 157 FPM CENTRES 50'6" 20° LEVEL
CONCENTRATE BINS HOPPERED CAPACITY 80 TONS
BOCHUM TRUCKS ¾ YD
AVERY WEIGHBRIDGE CAPACITY 60 CWTS
ALTERNATIVE
TO SMELTING PLANT
CONCENTRATES DRAINING VATS 20'0" DIAM × 8'0" DEEP
FILTER BOTTOMS CONNECTED TO KEY VACUUM PUMP
BOCHUM TRUCKS ¾ YD
FAIRBANKS WEIGHBRIDGE CAPACITY 60 CWTS
TO SMELTING PLANT

MOTOR LIST	No.	H.P.	FORM	STARTER
CRUSHER	1	30	T	DRUM CONTROL
CRUDE ELEVATOR & CONVEYOR	1	10	A	COMPENSATOR
ROLLS	2	35	K	"
MAINSHAFT FEEDER SCREENS ELEVATOR	1	15	K	"
TUBE MILLS	2	75	M	DRUM CONTROL
DORR THICKENERS	1	3	K	KNIFE SWITCH
CONCENTRATES ELEVATOR	1	9	S	COMPENSATOR
FLOTATION BOXES	1	75	M	DRUM CONTROL
OLIVER FILTER SECTION	1	10	K	COMPENSATOR
CONCENTRATES CONVEYOR	1	3		KNIFE SWITCH
DRAINING VATS VACUUM PUMP	1	10	K	METALLIC RHEOSTAT

MOUNT LYELL M. & R. CO. LTD.—FLOTATION PLANT
DETAIL FLOW SHEET.



ELL M. & R. CO. LTD.—FLOTATION PLANT.
GENERAL PLAN.



MOUNT LYELL M. & R. CO. LTD.—FLOTATION PLANT.
GENERAL PLAN.

bin existed, railway lines on the smelter tapping-floor level, 40 ft. lower, for despatching concentrates, and a suitable area between, on the site of the old blast furnaces, for the main building.

The finely crystalline character of the sulphides in the Lyell Comstock ore rendered gravity concentration inapplicable, and led to the adoption of flotation concentration alone. Mill design was thus simplified.

Plate I. shows the flow-sheet with details, and Plate II. the general lay-out of plant in plan.

Coarse-Crushing Section.

Ore is received from the Lyell Comstock mine in self-discharging hoppered trucks of 10 tons capacity (159 cub. ft.) These were constructed locally. Six trucks make up an ore rake, which is hauled by 10-ton Krauss locomotives of 60 h.p., tractive force 6490 lb. This ore is received on three days per week at the rate of 120 tons per day.

The ore from the North Mount Lyell mine is drawn in 1¾-ton trucks from bins at the top of the main Mount Lyell haulage.

All ore is weighed on the main smelter Pooley 75-ton weighbridge.

On account of limited bin accommodation, the ores are inadequately mixed, and consequently treatment has to be constantly varied as required by the different classes of ore.

The crude ore bin is lined with discarded manganese steel crusher jaw faces, and the only attention required is the occasional renewal of steel lining plates on the face of the bin.

An old Krupp crusher of the Blake type was utilized, with cast-iron body in a single piece. The back toggle was made a shearing toggle with twelve 1-in. rivets. Imported Sheffield manganese steel jaw faces have an average life of 6100 tons of ore crushed, against 4500 tons for Australian manganese steel. The latter have shown large variations in quality, though the manganese contents are similar, probably indicating irregularities in the heat-treatment. The crusher is driven at 240 r.p.m. by a 9-in. camel-hair belt, and set to crush to 2 in. A fine water spray is provided immediately above the jaw opening, to allay dust.

At the outset, considerable difficulty was experienced in wet weather in extracting Lyell Comstock ore from the crude ore bin on account of its "puggy" nature, its moisture at times reaching 10 %. This was overcome by making an enlarged door opening, 4 ft. 3 in. long by 1 ft. 9 in. high, with a radial door 3 ft. 10 in. long, and sluicing the ore in the bin with just sufficient water to form a "slurry" of the fines. The coarse ore discharges readily off the end of the conveyer into No. 2 fine-ore bin, while the "slurry" adheres to the conveyer belt, passes round the delivery drum, and is scraped off into a launder that delivers to the "raff" elevator. It is thus immediately eliminated and treated. The adoption of this "wet system" has rendered it possible to handle this class of ore without the least difficulty or loss of tonnage, and is an important factor under local conditions.

Fine-Crushing Section.

Ore is delivered to the screens from the fine-ore bins, which are fitted with ratchet doors, by means of corrugated roller feeders, and the undersize is thereby eliminated before roll crushing.

The screens are the Broken Hill North mine type. Perforated steel plates, either 7/64-in. dia. hole by .194-in. centres by 16 gauge, or ⅛-in. dia. hole by .22-in. centres by 14 gauge, are used, and have an average life of 2150 tons of crude ore screened. Soluble copper from the open-cut Lyell Comstock ore at times materially reduces the life of the screen plates. The connecting rods are built up of three plies of 4-in. by ½-in. ash, with ¼-in. plate cover. The screen is set at a 5° slope, and half of the screen is below water-level. The power required is about 2 h.p. each. Holes are bored in the screen boxes, so that surplus water overflows into the cast-iron lined chutes, leading to the rolls. The undersize passes out of the screen box through a 1¼-in. dia. wooden plug, and the discharge averages 25 % solids.

The oversize passes through the rolls, then is elevated by the "raff" elevator back to the screens. The flanged roll is belt-driven by 11-in. camel-hair belting, and the plain roll is gear-driven through twin wheels, the speed being 24 r.p.m. Chrome steel roll shells have a life of 9000 tons of ore crushed, against 5100 tons for carbon steel shells.

The screen undersize is elevated in the "fines" elevator and passes through the sampler to a diaphragm cone classifier and dewaterer with an automatic regulator, as illustrated in fig. 1.

The sliding weight requires adjustment for the two ores, greater leverage being necessary for that of North Mount Lyell. An arrow attachment in a prominent position serves to indicate the position of the cast-iron plug, and is useful in detecting irregularities, which are very rare, as the regulation is almost perfect. The cone discharge averages 26% moisture. The plugs have a life of four months and the suspension rods two months.

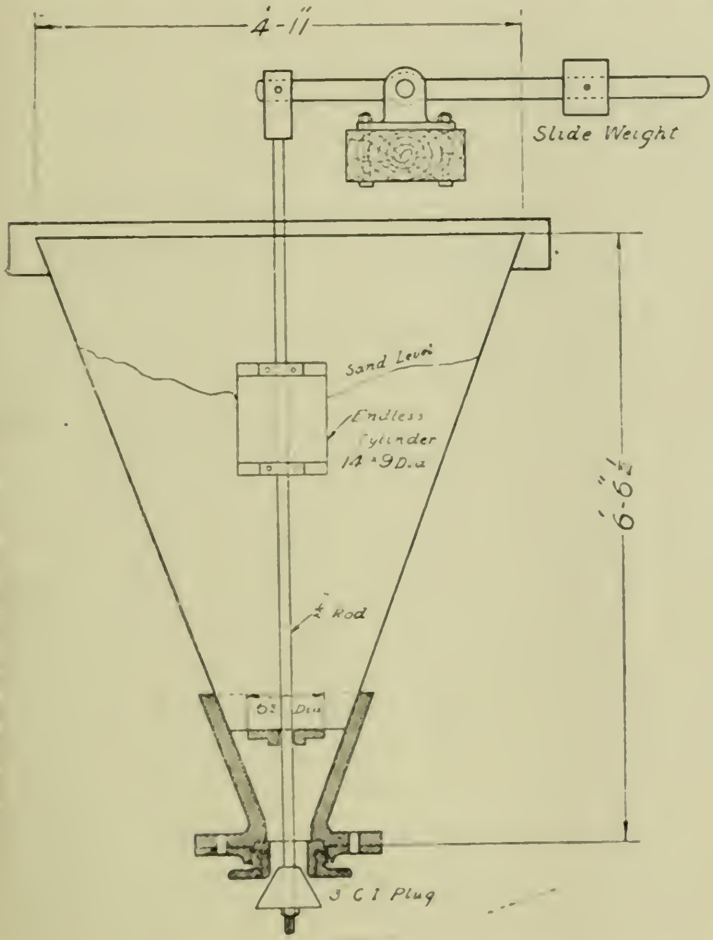


FIG. 1.
DIAPHRAGM CONE CLASSIFIER WITH AUTOMATIC REGULATOR.

The following are typical grading tests on the cone products:—

Mesh I.M.M.	Lyell Comstock.			North Mount Lyell.		
	Feed. %	Spigot. %	Overflow. %	Feed. %	Spigot. %	Overflow. %
+ 20 ..	47.7	62.2	—	63.6	65.9	—
+ 40 ..	14.4	12.6	—	12.3	15.0	—
+ 60 ..	7.1	5.5	—	4.2	5.8	—
+ 90 ..	6.8	10.2	—	4.2	4.5	.36
+120 ..	5.5	1.2	2.5	3.9	2.8	1.1
+150 ..	3.7	6.4	3.8	1.1	.8	1.2
—150 ..	14.8	1.9	93.7	10.7	5.2	97.34
	100.0	100.0	100.0	100.0	100.0	100.00

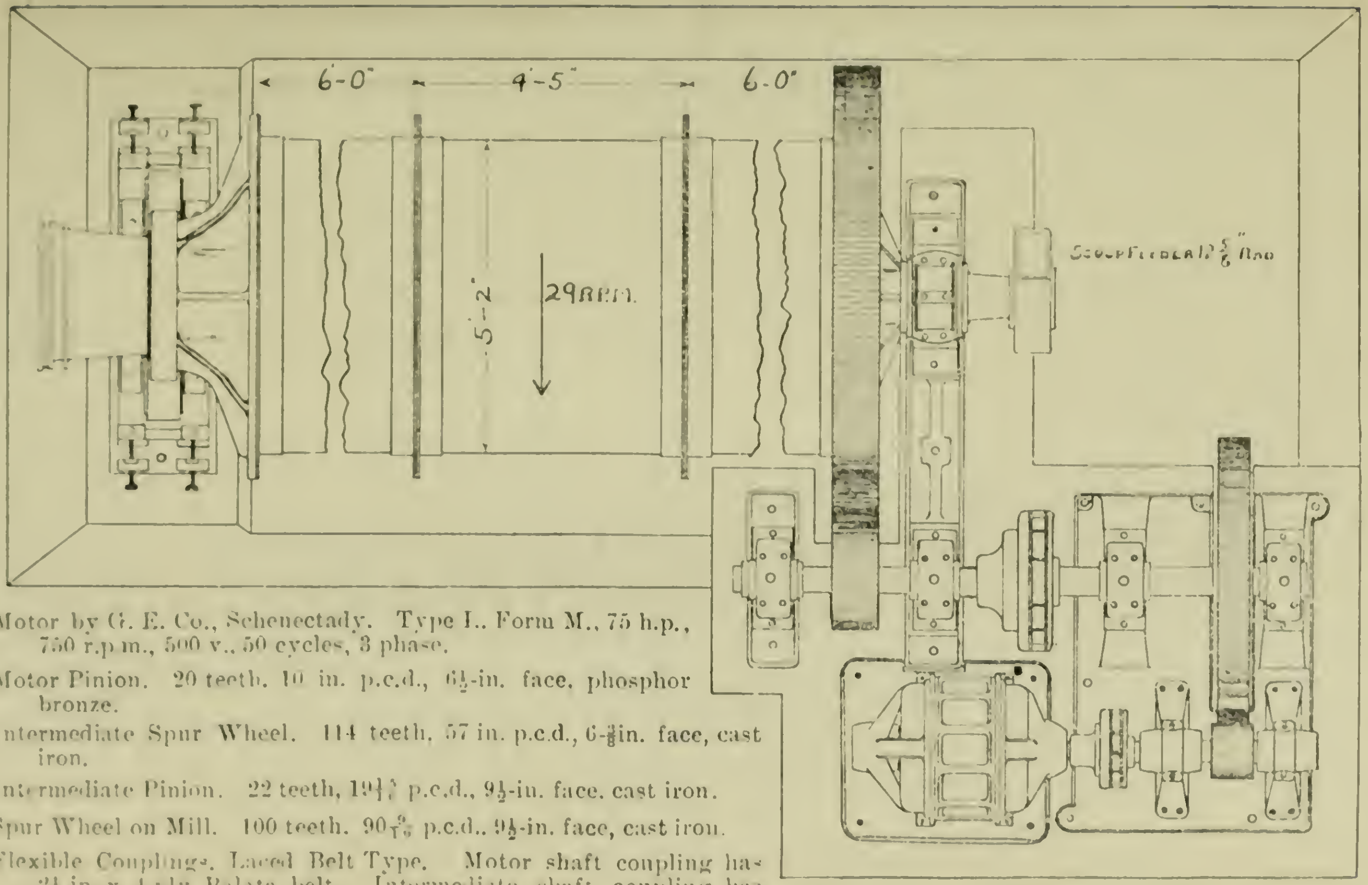
Tube Milling.

On account of the limited room available for the plant, gear-driven tube mills were adopted. These are driven by 75 h.p. motors, and have flexible couplings on both rotor and counter shafts. For the purpose of standardizing motor speeds generally on the works, 750 r.p.m. motors were used, but this high pinion speed cannot be recommended. Fabroil pinions have a life of about five months, but better results are obtained with locally-made phosphor-bronze pinions, run in an oil bath, in which case phosphor-bronze bearings are used on the rotor shaft. The mills are run in both directions of rotation, thereby extending the life of pinions and inside liners.

The mills are 16 ft. long by 5 ft. dia., with a hollow trunnion bearing on the feed end, and a forged steel tyre 2 ft. 9 5/16 in. dia. running on cast-steel rollers on the discharge end. The shell is built in three sections, bolted together by means of heavy angle irons.

The liners are local hard cast-iron ribbed liners, and have a service of about 25,000 tons. The wear on the end liners, which are also ribbed, is more severe, and these are replaced individually as required.

The mills are equipped with scoop feeders with a radius of 12⅝ in., and through these the daily pebble charge is fed. Owing



Motor by G. E. Co., Schenectady. Type I., Form M., 75 h.p., 750 r.p.m., 500 v., 50 cycles, 3 phase.

Motor Pinion. 20 teeth. 10 in. p.c.d., 6½-in. face, phosphor bronze.

Intermediate Spur Wheel. 114 teeth, 57 in. p.c.d., 6-⅜in. face, cast iron.

Intermediate Pinion. 22 teeth, 19$\frac{15}{16}$ p.c.d., 9½-in. face, cast iron.

Spur Wheel on Mill. 100 teeth. 90$\frac{9}{16}$ p.c.d., 9½-in. face, cast iron.

Flexible Couplings. Laced Belt Type. Motor shaft coupling has 2½ in. x 4 ply Balata belt. Intermediate shaft coupling has 4 in. x 4 ply rubber belt.

FIG. 2.

ARRANGEMENT OF TUBE MILL.

to the irregularity in supply and quality, and also the high cost of flint pebbles, Tasmanian quartzite pebbles are now used. These average 2½ in. to 4 in. in size, and the consumption amounts to 11 lb. per ton of ore.

Fig. 2 shows the general arrangement of a tube mill.

The following grading tests exemplify the work of the tube mills :—

Mesh I.M.M.	Lyell Comstock.		North Mount Lyell.	
	Feed. %	Discharge. %	Feed. %	Discharge. %
+ 20	62.2	—	65.9	—
+ 40	12.6	2.1	15.0	2.4
+ 60	5.5	6.2	5.8	6.9
+ 90	10.2	15.4	4.5	13.0
+120	1.2	8.7	2.8	8.1
+150	6.4	3.1	0.8	5.1
−150	1.9	64.5	5.2	64.5
	100.0	100.0	100.0	100.0

The moisture averages 26 %—*i.e.*, that of the cone spigot product; and the temperature rise is 18°—from 56° F. to 74° F.

DORR THICKENERS.

Two Dorr thickeners take the overflow from the diaphragm cone classifier, and are of the standard design for 20 ft. dia. tanks. No overload alarm is used, and an examination of the spring at starting is all that is necessary. The speed is ⅛ r.p.m., and the discharge averages 40.0 % solids.

The tanks are of steel construction, with 3/16 in. plate shell and ¼-in. plate bottom. Gate valves on a 4-in. discharge pipe regulate the discharge.

The feed is laundered into a wooden box, 2 ft. square by 1 ft. deep, with a central pipe 8 in. dia., that extends 12 in. below the surface, covered by a screen to collect chips, etc. A diving ring, 30 in. dia. by 48 in. deep, of 1/16-in. plate, concentrically surrounds this pipe and prevents any surface eddies.

Flotation Section.

The tube mill and thickener discharge join in the boot of the "feed elevator," which delivers to a balance cone, 2 ft. 6 in. dia. by 3 ft. 6 in. deep, at the head of the flotation boxes. Pebble fragments that escape the discharge grating of the tube mills are caught on a screen at the elevator boot.

The main flotation unit is of the standard Minerals Separation type, and contains 12 agitation and spitz boxes. The agitation boxes are 2 ft. 3 in. square by 3 ft. 10 in. deep, and have cast-iron liners. The stirrers are 4-bladed, 19 in. dia., revolving at 320 r.p.m., driven by a $\frac{1}{4}$ twist drive of 4-in. by 4-ply Balata belt, and the 2-in. shafts are equipped with S.K.F. radial and thrust ball races. The line shaft, which is 4 in. dia., is equipped with five S.K.F. ball races and driven by a 75 h.p. motor with 14-in. camel-hair belting. Two-bladed paddles, revolving at 19 r.p.m., are provided for skimming off the float at the lip of the spitz boxes.

The addition of frothing media is made to the tube mill feed, with such additions as may be necessary at the flotation boxes, generally only at starting up, until the thickener flow is normal and regular conditions are obtained. A mixture of one part of eucalyptus oil to two parts of coal tar is fed by a disc feeder to the diaphragm cone discharge before being split between the two mills, and eucalyptus oil to each tube mill through $\frac{1}{4}$-in. pet cocks from pipes connected to a supply tank. The tar consumption is .1 lb. and the eucalyptus oil .8 lb. per ton of ore.

Compressed air is introduced immediately under No. 1 stirrer in limited quantity, and tends to produce a crisper float on the first boxes.

The float from the last four spitz boxes is returned as a middling to the feed elevator.

The dilution of the flotation boxes is maintained at about $4\frac{1}{2}$ to 1. On account of the difficulty in settlement of the slimed gangue of the Lyell Comstock ore and its tendency to "sicken" the float and lower the grade of concentrates, the flotation section is arranged in open circuit—*i.e.*, there is no return tailings water.

Sulphuric acid is not found to be necessary in the treatment, although indicated in the experimental investigation of North Mount Lyell ore. The improvement in grade of concentrates by the use of acid is offset by a drop in recoveries.

The flotation solutions are not heated, but conditions improve with rise in temperature. The temperature of solution varies from 47° F. in winter to 74° F. in summer.

As the height of the discharge from the flotation boxes above the tailings launder was sufficient to place a single cascade box, a unit, as shown in cross section in fig. 3, was subsequently installed. This box acts as a tailings scavenger and returns some pyrite as a middling, and at the same time is a guide in the operation of the flotation boxes, as it indicates changes in dilution and irregularities in the float.

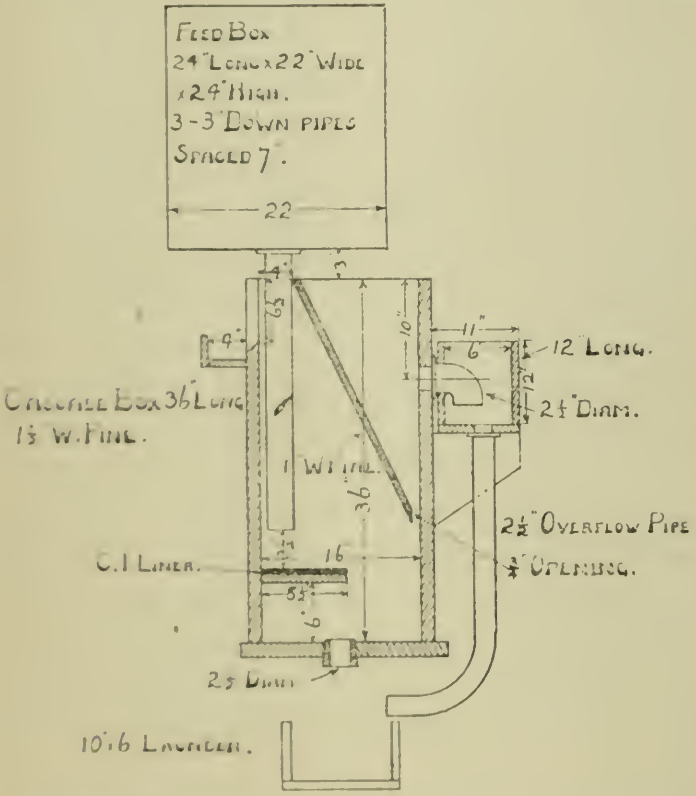


FIG. 3.
CASCADE UNIT.

A separate flotation unit, the subject of Australian Patent No. 2353/16, by the author, was installed to re-treat the concentrates from the Minerals Separation flotation boxes. It

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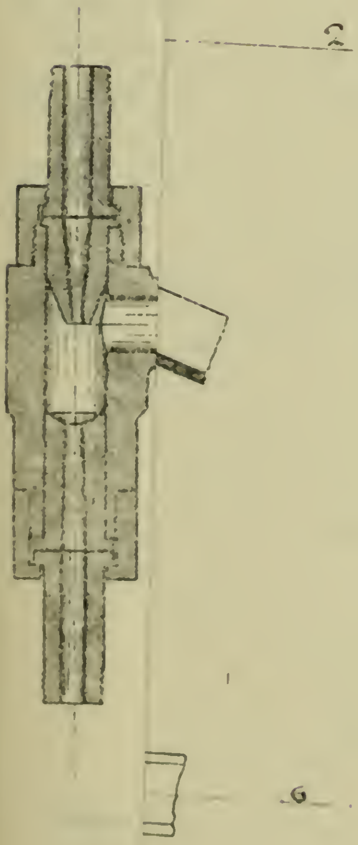
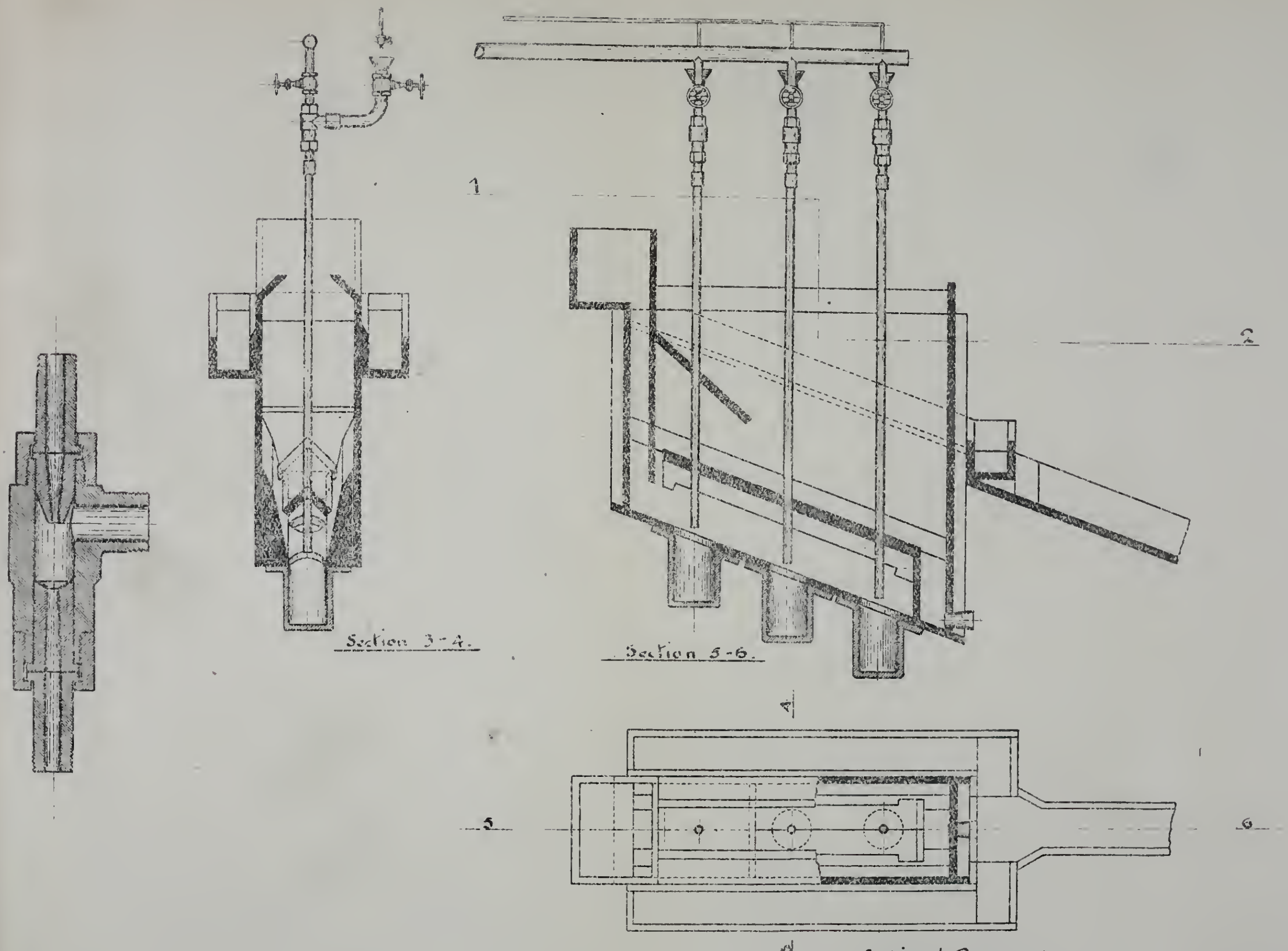




Section 3-4.

Section 5-6.

Sectional Plan 1-2.

HIGH-PRESSURE WATER JET FLOTATION UNIT.

consists in forcing atomized air into the oiled pulp, in a launder-shaped box, by means of high-pressure water through an ejector. Plate III. shows the arrangement of a three-jet unit.

Water at 80 lb. pressure, through a 3/16 in. jet in the ejector, is used. Excellent results have also been obtained on crude ore pulp, as well as in re-treatment of concentrates. The quantity of water returning with the middling from this unit, in addition to returns from the main boxes, filter, and cascade cleaner, produces an excessive circulation, and since the introduction of the cascade cleaner this re-treatment unit has not been in constant operation, although conditions in the main boxes were improved by the addition of the emulsified solution.

The same type of water-pressure ejectors is used to pump out the overflow pits, adjoining the elevator boots.

The following grading test on flotation products was made on mainly North Mount Lyell ore :—

	Mesh I.M.M.	Wt. %	Cu %	Fe %	Insols. %	Recovery % Cu.
Feed—	+ 40	4.72	1.8	6.4		
	+ 60	10.14	2.17	8.3		
	+ 90	15.36	2.35	9.2		
	+120	9.23	2.45	9.8		
	+150	4.11	2.9	10.1		
	−150	56.44	3.12	8.7		
	Bulk	100.00	2.77	8.78		
Concentrates—	+ 40	1.17	8.25	26.6	37.3	56.1
	+ 60	6.47	7.5	25.2	36.8	75.9
	+ 90	11.7	8.1	26.6	32.2	81.4
	+120	8.46	8.6	28.6	28.6	91.1
	+150	5.08	9.3	29.8	24.1	96.8
	−150	67.12	10.9	24.8	32.0	95.2
	Bulk	100.00	10.01	25.5	34.6	90.9
Tailings—	+ 40	6.4	.9	3.8		
	+ 60	10.6	.68	2.5		
	+ 90	14.8	.45	1.6		
	+120	4.5	.3	1.25		
	+150	4.0	.28	1.25		
	−150	59.7	.21	1.79		
	Bulk	100.0	.34	1.89		

Filtering Concentrates.

Three steel draining tanks, 30 ft. dia. by 8 ft. deep, with the usual filter bottom, consisting of a grating covered with hessian and cocoanut matting, were originally provided, also a wet vacuum pump. Froth rings and overflow launders were attached. After one week's drainage the moisture averages 15 %.

Subsequently an Oliver continuous-revolving drum filter, 8 ft. dia. by 8 ft. long, having a filter area of 200 sq. ft., was installed, and has given excellent service. Concentrates are elevated to the filter direct from the M.S. boxes without any thickening, and average 52 % moisture. The drum revolves one revolution in eight minutes, and the cake produced varies from ¼ in. to 2 in. in thickness, and contains 11.5 % moisture.

The following test indicates the work of the filter :—

H_2O in feed	52.0 %.
H_2O in cake	11.5 %.
Vacuum	22 in.
Estimated capacity ..	600 lb. per sq. ft. per 24 hours

Grading.

Mesh I.M.M.	Wt. %	Cu %	Fe %	SiO_2 %	Al_2O_3 %
+ 60	6.4	14.85	23.0	26.0	.6
+ 90	8.6	9.45	26.5	27.4	1.2
+120	7.5	10.9	27.0	22.6	3.9
+150	6.3	11.7	27.2	21.6	4.6
−150	71.2	9.55	23.9	21.0	6.5
Bulk	100.0	10.11	24.5	22.0	5.35

The depth of pulp varies with the working of the filter, and submerges the drum up to 3 ft. 6 in., lower levels yielding a drier cake and higher levels greater capacity.

No steam raising of the temperature of pulp has been tried, but the experience of others is that it yields a drier cake and increases capacity.

The drum is wound, over the canvas, with 14-gauge copper-clad steel wire, the turns being about ⅝ in. apart. It takes about 16 hours to re-canvas and re-wire the drum. The canvas lasts about eight months, and the hessian under the canvas two years. One recent canvas handled 5157 tons concentrates. The canvas is occasionally hosed and scrubbed. The scraper requires particular attention, and is periodically filed, reversed, or renewed.

The air-lifts and emergency air-agitation pipes were not found satisfactory, and were discarded. The speed of the mechanical agitators was increased to 74 r.p.m. The original agitator shaft consisted of a heavy 3-in. pipe flanged to stub shafts on each end. It was soon found necessary to use a solid 3-in. shaft. Wrought-iron paddles spaced 9 in. apart, and alternatively right and left hand to avoid thrust, have been used, but, on account of the presence of copper in solution, cast-iron paddles are now being tried.

The attendant on the flotation boxes also operates the filter, which requires a minimum of attention.

The filter delivers the concentrates on to an 18-in. inclined conveyer, that in turn delivers to concentrates bins.

Concentrates are loaded into ¾-yd. Bochum trucks, and drawn to the smelters, distant about 200 yds., by horse.

SAMPLING.

The feed sample is taken in the fine-crushing section by a sampler developed on the Broken Hill South mine, consisting of two inverted hollow cones, rotating on the same axis in opposite directions at different speeds, and having knife-edge cuts through them at different radii from the above axis.

Grab samples are taken of concentrates and tailings at regular intervals for daily records.

Filtered concentrates are officially sampled as despatched to the smelters by means of cheese samplers.

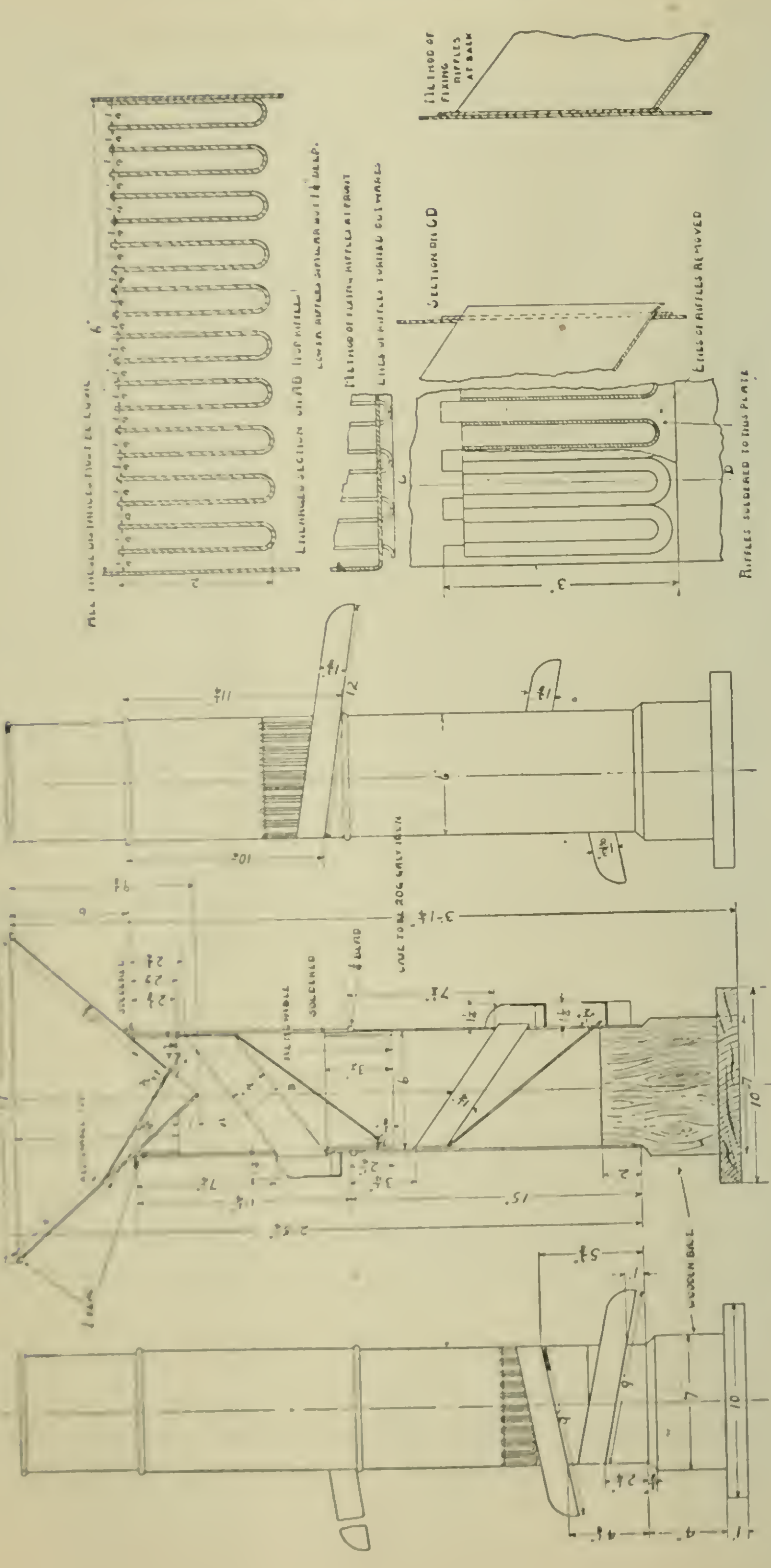

ALL THESE DISTANCES MUST BE EQUAL
6"
ENLARGED SECTION ON AB (TOP RIFFLE)
LOWER RIFFLES SIMILAR BUT 1¼ DEEP.
METHOD OF FIXING RIFFLES AT FRONT
EDGES OF RIFFLES TURNED OUTWARD
C
SECTION ON CD
EDGES OF RIFFLES REMOVED
D
RIFFLES SOLDERED TO THIS PLATE
3"
METHOD OF FIXING RIFFLES AT BACK
11¾
10"
12
6"
3'-1¾
LINE TO BE 20G GALV IRON
SOLDERED
FLEXIBLE
7¼
15"
2'5"
10
WOODEN BALL
5¼
7
10

FIG. 4.
SAMPLE REDUCER.

Pulp samples are reduced in a very useful and accurate sample reducer, as shown in fig. 4. The reducer is made in three parts for the purpose of cleaning and inspection.

On account of the difficulty in settlement of slime and the distance of the assay office from the plant, filters for samples were devised, and have proved very useful. Fig. 5 shows the arrangement and general details.

ELEVATORS.

Elevators are framed of 6-in. by 3-in. Oregon with 6-in. by ⅞-in. pine lining. The width between lining is 2 ft. 2 in., and the depth 6 ft. All top and bottom drums are 36 in. dia. by 15 in. face by 5/16 in. crown by 4 in. shaft, with ring oil-bearings on top and solid bearings with brass bushes on the bottom.

All belts are 12-in. by 8-ply Balata, and driving belts 6-in. by 6-ply Balata. Buckets are riveted mild-steel plate, weigh 7½ lb., and have 190 cub. in. capacity.

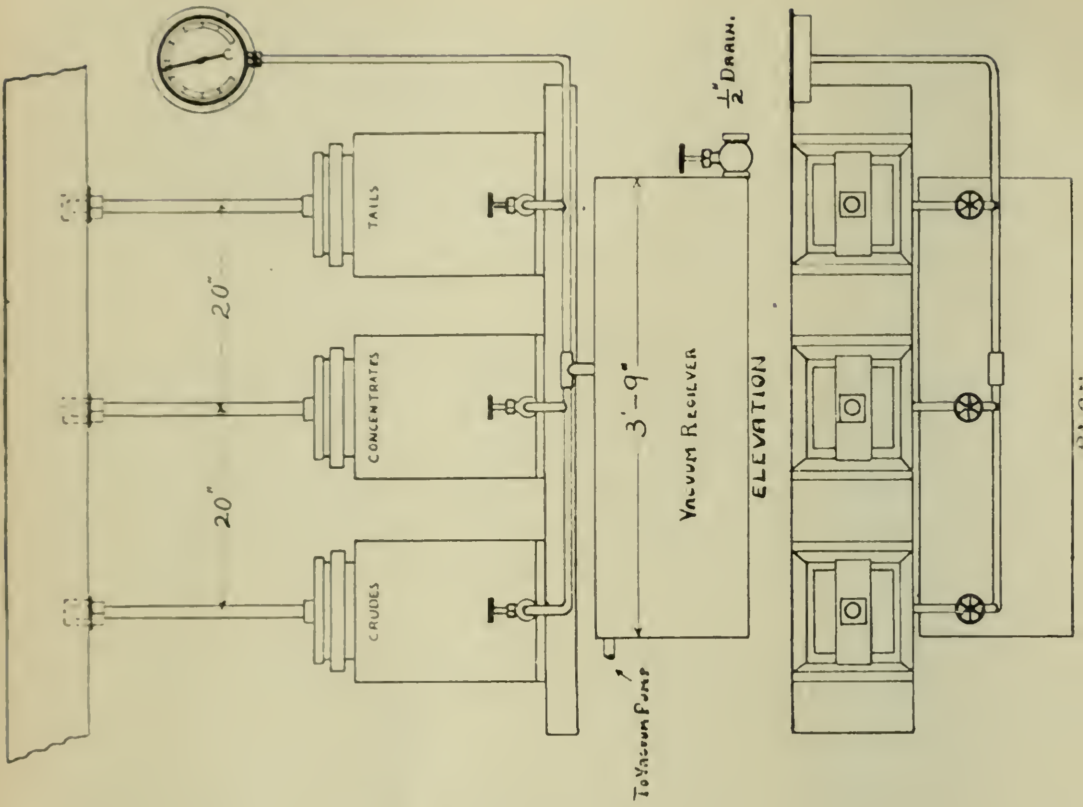
Sand guards are provided on the bottom shaft, deflecting saddle above the drum at 45°, carrying rubber scrapers, and adjustable lips at the discharge. The centre of the top drum is 3 ft. 9 in. above the discharge lip, which gives a satisfactory delivery at the speeds employed.

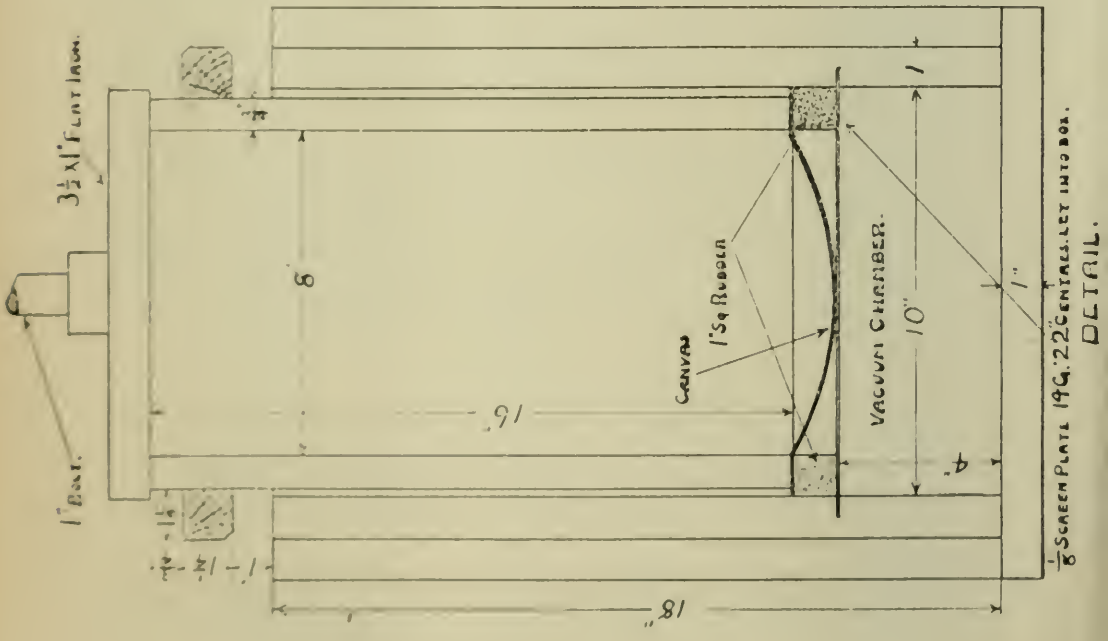
The feed and concentrates elevator belts have been running for four years without renewal. The crude elevator belt has the most severe duty, and lasts about 35 weeks, or 23,000 tons, against 58,000 tons for the raff elevator, and 44,000 tons for the fines elevator.

TAILINGS DISPOSAL.

The tailings are run into a dam built on top of the old granulated slag dump. There is little bond in the tailings, and so far the walls have been built of discarded coke bags filled with tailings.

Towers to take the overflow are spaced about 45 ft. apart, a few feet inside the wall, and connected to launders that discharge into


TAILS
CONCENTRATES
CRUDES
20"
20"
3'-9"
VACUUM RECEIVER
ELEVATION
½" DRAIN.
TO VACUUM PUMP


1" BOLT.
3½ x 1" FLAT IRON.
8"
16"
CANVAS
1" SQ. RUBBER
VACUUM CHAMBER.
10"
1"
1"
4"
18"
⅛ SCREEN PLATE 14G. 22" CENTRES. LET INTO BOX.
DETAIL.

the creek. The towers are 10 in. by 10 in. inside dimensions, and have 2-in. staggered holes, which are blocked up as the dam is desired to be raised.

POWER.

Power is generated at the Lake Margaret power station at 6600 volts, transformed to 3300 volts at the main sub-station, and delivered to the plant transformer station. This contains two banks of transformers, each bank consisting of three single-phase 75 kw. 3300 v. to 550 v., delta connected, Westinghouse oil-cooled shell-type transformers.

There is also a 20 kw. Weymouth 550 v. to 220 v. and 110 v. transformer for heating and lighting.

The current for the magnet on the crude-ore conveyer is provided by the 500 v. D.C. motor generator set at the main sub-station, and is cut down to 250 v. on the magnet by series resistances. The magnet takes about 1.2 amps.

The total power consumption averages 27.4 kw. hr. per ton of ore treated.

LABOUR.

The following is the labour apportionment :—

——	DAY SHIFT.	AFTERNOON SHIFT.
	Foreman.	Shift Boss.
Crusher hand	1	1
Ore Bins, Conveyer, and Offsider to crusher hand	1	1
Rolls, Screens, Feeders	1	1
Cone, Tube Mills, Thickeners	1	1
Sampler	1	1
Spitzman, Filter	1	1
Oiler	1	1
Boy	1	
Leading hand	1	
Loading concentrates and attending to tailings dam	2	

Day and afternoon shifts are worked, with the exception that no afternoon shift is worked on Saturday, which is replaced by a shift on Friday night. This arrangement involves a quick shift each week for all men who change shift, but the men appreciate the Saturday evening free from work.

Costs.

The following is an approximate dissection of operative costs, excluding royalty, for the year 1919:—

	s.	d.
Coarse crushing	0	11½
Fine crushing	1	3½
Tube milling	1	2
Thickening	0	1½
Flotation	1	4
Tailings disposal	0	0½
Sampling	0	4½
Power	0	4
Assaying	0	10
General (supervision, testing, &c.) ..	0	8½
Handling concentrates	0	9
Total	7	11

Treatment of Concentrates.

The concentrates are sintered in a Dwight-Lloyd machine, and the product goes to the blast furnaces. A nodulizing kiln, fired with pulverized coal, has also been erected, but not yet put into operation on account of shortage of coal.

The following is the main data of the Dwight-Lloyd machine:—

Grate area	300 in. x 30 in.
Grate speed	15 in. per min.
Vacuum in suction boxes	12 in. water.
Ignition	Wood, burned in standard ignition box
Fan maker	Johns Waygood.
Impeller	5 ft. 6 in. diam., 900 r.p.m.
H.P.	50.
Intake	4 ft. x 4 ft.
Outlet	3 ft. 1 in. x 2 ft 1 in.

The charge averages 60 % concentrates, 30 % blast-furnace flue dust, and 10 % ore screenings, and contains 11 % moisture.

The sulphur contents of the charge average 19 % and the sinter 6 %. The capacity is 50 to 55 tons of the mixture per 24 hours.

CONCLUSION.

The object of this paper is to present practical working details, without any attempt to discuss theories, of a small plant that has been entirely successful.

The author is indebted to the management of the Mount Lyell Mining and Railway Co. Ltd. for permission to publish data.

PROCEEDINGS AUS. I.M.M.] [N. S., No. 38, 1920

TREATMENT OF HARD WATER FOR FURNACE JACKETS.

By A. S. ARMSTRONG.

AT Broken Hill, Northern Rhodesia, two water jacket lead furnaces have been in operation for the past three years. The furnaces were erected in war time, and only absolute essentials were procurable.

The water for the jackets was obtained from wells adjacent to the works, in a dolomite formation, and this water contained

$CaCO_3$	...	...	15.4 parts per 100,000
$MgCO_3$	...	...	13.5 ,, ,, ,,

There being no water-softening plant, except a small one capable of treating water for the power plant only, this water was found to make a heavy scale in the jacket.

During 1917 several jackets were burnt through, resulting in serious trouble and loss of output.

In order to avoid this, furnaces were stopped twice a month for 8 hours and scale was removed as far as possible.

In addition to the scale trouble during the summer months, a green slime grew in the supply tanks and occasionally became detached from the tank and collected in the cocks near the jackets. This caused risk to the jackets and was difficult to remove without a stoppage of the furnace.

In 1918, bundles of wattle bark were placed in the hot well at the rate of one ton per month. These extracted the tannin and added from 0.5 to one part of tannin per 100,000 to the circulating water. The hot water was cooled over a brushwood cooling tower and returned to the supply tanks. The well water required to make up the wastage was estimated at 40,000 gal. per day.

[This paper is separately bound, and may be, if so desired, detached complete from this number.]

During the past two years, since the wattle bark has been in use, no jackets have been burnt. Stoppages have been reduced from 16 hours per month to 4 hours per month. Any scale which forms is of such a porous nature that it is easily removed.

During the summer months the green slime does not grow.

The cost of wattle bark at Broken Hill, Northern Rhodesia, is £7 per ton. The advantages gained by its use are equal to what might be expected from an expensive water-softening plant, and the operating and upkeep of such a plant are avoided.

PROCEEDINGS AUS. I.M.M.] [N. S., No. 39, 1920.

Papers and Discussions.

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THE GEOLOGY AND ORE-DEPOSITS OF THE WALHALLA-WOOD'S POINT AURIFEROUS BELT.

BY N. R. JUNNER, M.C., D.Sc., D.I.C., London (1851 Exhibition Scholar, University of Melbourne, 1913).

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INTRODUCTION.

(*a.*) *General.*—The following thesis is an outcome of an investigation undertaken by the writer, at the suggestion of Professor Skeats, of the dykes and associated auriferous reefs of the Walhalla-Wood's Point belt, with the view of determining what relation, if any, existed between the petrological nature and the extent of metasomatic alteration undergone by the dykes, and the genesis and localization of the gold.

Although the greater part of the writer's time in the field and laboratory was occupied in studying the dykes and auriferous occurrences, a study was also made of the general geology as a basis for the special investigation. In addition, it soon became evident in the field that secondary enrichment had played a marked part in re-concentrating the gold, and some interesting data in this connection have been collected. For example, indubitable evidence has been found of nuggets of gold having been formed by secondary processes.

In the writer's journeyings in the field the excellent topographical and geological maps by Messrs. W. Baragwanath and O. A. L. Whitelaw have been of invaluable assistance. One must travel through the ranges to appreciate fully the difficulties of topography and undergrowth and the lack of comfort under which these gentlemen worked in producing such accurate results.

The completion of this research, which was started in 1912, has been retarded by the writer's absence on military duties during the period September, 1914, to July, 1919.

(*b.*) *Situation.*—The area dealt with in this paper is the belt of country about 12 miles wide extending from Walhalla in the south to Jamieson at the northern end, and includes the one-time important gold-fields of Walhalla, Toombon, Donnelly's Creek, Aberfeldy, Jericho, Matlock, Wood's Point, Gaffney's Creek, Ten-Mile, and Enoch's Point. The total area embraced is about 600 sq. miles.

(*c.*) *History of Gold Mining, &c.*—Most of the gold-fields of this belt were discovered between 1860 and 1864, and mining flourished between these dates and 1875. From this time onwards the usual fluctuating periods of activity and depression were the rule, until at the present day the industry is in a very decadent state.

The largest yields came from the famous Cohen's line of reef at Walhalla. It has been worked to a depth of 3375 ft. vertically, and has yielded approximately 1,478,000 oz. of gold and paid £2,378,290 in dividends, of which total £1,283,400 were paid by the Long Tunnel mine and £788,640 by the Long Tunnel Extended.

Of the other mines in this belt, the largest producers have been the Morning Star, A1, All Nations, New Loch Fyne, and the Rose of Denmark.

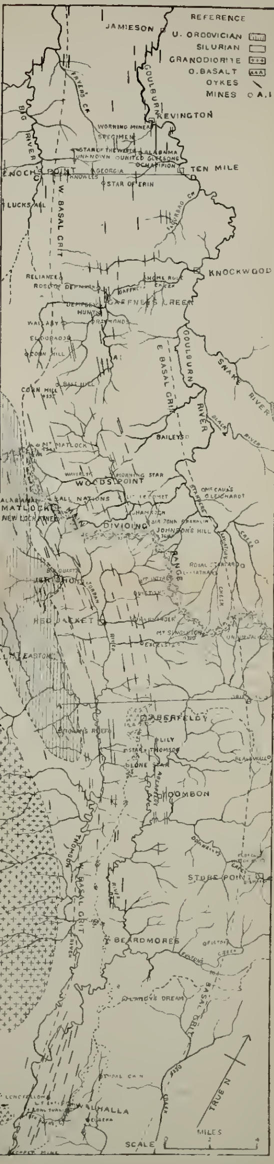
Approximate total yields from these mines are given below, viz. :—

Name.	Gold.	Depth.
Morning Star	£1,010,000	0–400 ft.
All Nations	132,000 oz.	0–450 ft.
A1	£500,000	0–1200 ft.
New Loch Fyne ..	100,000 oz.	0–700 ft.
Rose of Denmark ..	50,000 oz.	0–1300 ft.

(*d.*) *Acknowledgments.*—In the foremost place the writer desires to thank Professor Skeats for kindly criticism and advice on many occasions and for granting numerous facilities and much assistance in the University Geology Laboratory.

JUNNER—ON THE GEOLOGY AND ORE-DEPOSITS OF THE
WALHALLA—WOOD'S POINT AURIFEROUS BELT

PLATE I.



GEOLOGICAL LOCALITY PLAN

To Professor W. W. Watts, F.R.S., of the Royal College of Science, London, he is greatly indebted for valuable assistance and for kindly interest in the work.

To the Director of the Geological Survey, Mr. H. Herman, he wishes to record his thanks for granting facilities to see unpublished plans and certain thin sections of rocks from this belt; also for two rock analyses made for him at the Mines Department Laboratory. To his officers, Mr. W. Baragwanath, Mr. O. A. L. Whitelaw, Mr. A. M. Howitt, and Mr. T. W. Dewey, he is grateful for many courtesies and much valuable information.

To Mr. Baragwanath particularly he is indebted for whole-hearted assistance in every possible way.

To Mr. M. O. Copland, Principal of the School of Mines, Ballarat, his thanks are due for helpful advice and for numerous references to the literature.

To the various mine managers of this belt the writer is greatly indebted for the cordial assistance granted him in carrying out his investigations and for the hospitality accorded him on many occasions. In particular, he desires to thank, in this connection, Mr. J. Friel, manager of the New Loch Fyne mine, Matlock; Mr. J. Till, manager of the A1 mine, Gaffney's Creek; Mr. Kenny Smith, manager of the Eldorado mine, Gaffney's Creek; Mr. Hogarth, manager of the Rose of Denmark mine, Gaffney's Creek; and Mr. F. Higgins, of Enoch's Point.

To Messrs. Tallin and Sweeting, of the Geological Department of the Imperial College of Science, London, the writer is grateful for certain rock-sections and microphotographs, and to Mr. Dudley King, of the Melbourne University Geological Department, for numerous rock-sections.

To the Commissioners of the Royal Commission of the Exhibition of 1851, whose Research Scholarship made this investigation possible, the writer is indebted for many kindnesses.

Finally, the writer desires to express his indebtedness to Dr. Summers and Mr. F. A. Singleton, B.Sc., of the Melbourne University, for supervising the editing of this paper during the writer's absence.

PART I.—PHYSIOGRAPHY, GENERAL GEOLOGY, AND PETROLOGY.

1.—PHYSIOGRAPHY.

The region described in this paper is characterized by marked relief—more than 2000 ft. near Wood's Point—and a youthful topography. Narrow valleys deeply indented in the Silurian and Ordovician bed-rocks are the rule.

The divides have a markedly level-topped character, suggesting a one-time plateau now highly dissected. The general slope of this plateau appears to have been to the south, as is evidenced from the following heights of certain Older Basalt and sedimentary residuals :—

Older Basalt Residuals.	ft.	Sedimentary Residuals.	ft.
Mt. Buller	5911	Mt. Timbertop	4500
Connor's Plains	4340	Mt. Terrible	4000
Mt. Useful	4720	Main Divide	av. 4000
Aberfeldy	app. 3600	Aberfeldy	app. 3600
Moondarra, Walhalla	app. 2000	Walhalla (Black Diamond Hill)	2080

The northern limit of this plateau was possibly the Mansfield sunk land of Fenner (No. 15, p. 394).*

The Main Divide pursues a meandrine course in a general east and west direction through the centre of the belt. Its present position appears to have been determined by the greater activity of the north-flowing streams—namely, the Goulburn and Big Rivers—and it probably was at one time much further to the north, as suggested by Dr. Griffith Taylor (No. 47).

Throughout a very close relationship exists between stream-directions and the grain of the country. The following very important rivers which drain this belt—namely, the Goulburn, Thomson, Aberfeldy, and Big Rivers—run parallel to the strike of the Silurian and Ordovician sediments for long distances, and their main tributaries pursue courses at right-angles to the strike.

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* The figures in brackets throughout this paper refer to the list of publications shown on pp. 253-256

Fig. 1 illustrates in a striking manner this relationship between stream-directions and structural lines, strike, and jointing ("trellis drainage" of Brigham). In general the streams follow closely the anticlinal axes, and the divides and spurs the synclines.

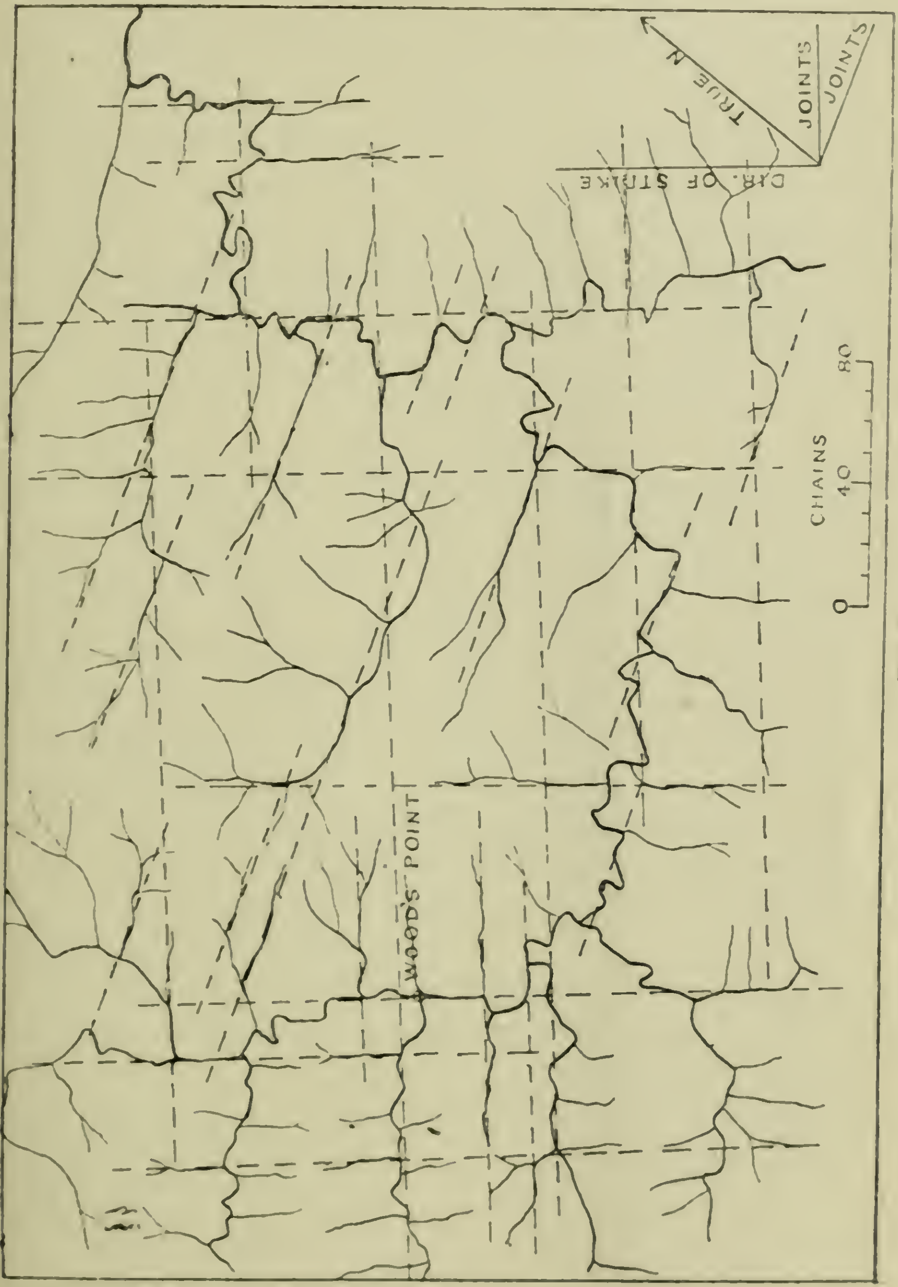

Fig 1.

Trellised Drainage of the Goulburn River near Wood's Point.

Showing relations between stream-directions and the strike and jointings of the Silurian strata.

Remnants of a former river-system are preserved in the form of coarse gravels, sands, and silicified conglomerate beneath residuals of Older Basalt in certain parts of this region. Good examples of these gravels can be seen at numerous places beneath the basalt patches on the divide between the Thomson and Aberfeldy Rivers from Aberfeldy as far north as Beardmore's. There is a southerly fall in the level of these gravels of nearly 500 ft. in the ten miles between these places. They appear to be relics of a stream flowing in a general southerly direction, which was buried by lava-flows from Aberfeldy, where, the writer is informed by W. Baragwanath, the basalt is nearly 1000 ft. thick.

2.—General Geology.

A.—SEDIMENTARY ROCKS.

(1) *General.*—The Walhalla-Wood's Point auriferous belt consists chiefly of a thick series of sediments of Silurian age.

Flanking these rocks on either side in the vicinity of the main divide are beds of Upper Ordovician age.

The relationship between the latter beds and the Silurian strata is not clear. According to E. J. Dunn (No. 12, p. 8), " the junction of the Silurian and Ordovician systems near the Royal Standard mine is very clearly marked with a distinct unconformity." However, no fossils have yet been found in this vicinity to indicate the presence of beds of Upper Ordovician age.

In the Yarra track section, north-west of Matlock, no structural break is evident between the two formations. The Upper Ordovician beds have a similar trend to the Silurian, and, although they are more cleaved, they do not appear to be any more intensely folded than the latter beds.

In the Jordan River section above Jericho, as pointed out by Mr. O. A. L. Whitelaw, the basal gritty sandstones and conglomerate of the Walhalla beds rest directly on the highly fossiliferous Upper Ordovician beds, while further south, near Mount Easton, shales and slates containing Monograptus intervene between these beds.

(2) *Upper Ordovician.*—Strata of this age appear in the cores of domed geanticlines near Mount Easton, Matlock, and the Big

River on the western flank of the belt, and near the Black River on the eastern side. Lithologically, these beds consist for the most part of black and grey thin-bedded slates and shales, with occasional thin bands of soft white and dense black sandstone. Certain loose-textured nodular beds of low specific gravity, with included lapilli of andesitic material, occur on the south-western flank of Mount Easton. They appear to be contemporaneous tuffs.

The Upper Ordovician in places has yielded a rich graptolite fauna. W. Baragwanath's fine collection from the Mount Easton area has been described by the late Dr. T. S. Hall (No. 20, p. 266).

The fauna corresponds closely with that of the Upper Glenkiln and Lower Hartfell beds—close to basal Bala—of the English nomenclature.

(3) *Silurian.*—Beds of Silurian age cover the whole of the central auriferous area of the belt. Their general order of succession is as follows:—

Yeringian (Upper Silurian)	Walhalla beds. Panenka beds.
Melbournian (Lower Silurian)	Monograptus beds. Black and grey mudstones and sandstones of Thomson and Big Rivers. Store Point–Mount Useful beds.

(*a.*) *Walhalla Beds.*—These beds occupy the central geosynclinal area between the eastern and western basal grits shown on the sketch map, Plate I.

They are in the main of shallow-water marine or estuarine origin, as is shown by the abundant ripple-marking, false bedding, mud-cracks, worm and crustacean tracks throughout these beds. Marine fossils are fairly common, and, although plant-remains are numerous, they appear to be of sea or estuarine origin.

The Walhalla beds may be subdivided broadly as follows:—

Upper Shales.
Holy Terror Grit.
Alternating Feldspathic Sandstone and Shale.
Basal Grit and Associated Limestones.

Upper Shales.—Stratigraphically, these are the highest beds of the Silurian series, and are found only in the troughs of the main geosynclinal. For the most part they are very thin bedded, highly cleaved. grey-green shales and slates with a little sandstone. Remains of plants referable to *Haliserites Dechenianus* Göppert. and *Bythotrephis divaricata* Kidston, are found in the basal members of these beds.

Holy Terror Grit.—This term has been applied by Mr. O. A. L. Whitelaw (No. 57, p. 12) to a very persistent band of fossiliferous grit on the eastern side of the main geosynclinal axis. On the western side this feature is not so well defined, and is represented by coarse-grained and gritty sandstones, which are fossiliferous in places.

The Holy Terror grit consists chiefly of rounded grains of quartz normally $\frac{1}{8}$ in. to $\frac{1}{4}$ in. in diameter, with occasional fragments of chert. slate, and sandstone.

Fossils are common, but they are generally in poor state of preservation. Some forms collected by Mr. Baragwanath from this grit in O'Keefe's Gully, near Aberfeldy, were described by Mr. F. Chapman (No. 7, p. 68) as *Atrypa reticularis* Linn. sp., *Orthis* (*Dalmanella*) *testudinaria* Dalman, *Fenestella,* and (?) *Cladopora.*

Alternating Feldspathic Sandstones and Shales.—The shales are thin bedded and grey-green and black in colour for the most part. Occasional thin bands of black carbonaceous shales are interbedded with them. Plant remains, referable to *Haliserites Dechenianus* Göppert, *Bythotrephis divaricata* Kidston, and other indeterminate forms occur in these beds. Yellow, brown, and black sandstones and gritty beds are common near the base of the Walhalla beds. Ripple-marking, false bedding. &c., are common in these beds.

Thin sections of the sandstone show the presence of a considerable amount of detrital igneous debris—plagioclase feldspar, chlorite, leucoxene. and fragments of chert and silicified ash.

Fossils are not uncommon, but in general their specific characters are difficult to determine owing to their poor state of preservation. They consist chiefly of crinoid remains, brachiopods, and corals.

Basal Grit and Associated Limestones.—The basal grit of the Walhalla beds is a well-defined feature traceable on either flank of the main geosynclinal axis from Walhalla to Jamieson. In the vicinity of the Thomson River copper mine this member is represented by a conglomerate made up largely of coarse pebbles of basic igneous rocks—hornblende diabase, variolite, &c.—derived possibly from rocks of Heathcotian age. It also contains pebbles of gneiss, quartz, black chert, quartzite, and sandstone (No. 29, p. 296).

In the northern portion of the belt the basal grit is coarse-grained and very quartzose. One specimen from Enoch's Creek, near Enoch's Point, consists mainly of rounded grains of vitreous quartz with occasional fragments of slate, chert, sandstone, and some igneous material.

Another specimen, from Standers Creek, is composed of grains of sub-angular quartz, chert, silicified ash, plagioclase, biotite flakes, pyrite, and red iron oxide. Muscovite is rare.

Poorly preserved fossils, chiefly crinoid columnars, orthoceras, and corals, are plentiful in the basal grit. *Chonetes cresswelli* Chapman, *Leptæna rhomboidalis* Wilckens sp., *Pleurodictyum megastomum* Dun, have also been described from it.

Lenticular patches of black coral and crinoidal limestone occur intercalated with the basal conglomerate at several points on the Thomson River, north of the copper mine, at the Tyers River, west of Walhalla, and at Deep Creek, on the east side of Walhalla.

These limestones have yielded a rich fauna of Yeringian (Gothlandian) age. The Favositidæ is abundantly represented. *Favosites forbesi* Ed. and Haime, *F. nitida* Chapm. *F. gothlandica* Lam. are common forms. In addition, *Cyathophyllum approximans* Chapm., *Heliolites interstincta* Linn. sp., fragments of *Stromatopora*, are not uncommon. Crinoid columnars, Trilobite remains, and *Girvanella* also occur in these limestones.

Chemically, the limestones consist chiefly of $CaCO_3$, as the following analyses show :—

	1	2	3
			%
$CaCO_3$	92.83	96.20	93.50
$MgCO_3$ ..	0.65	trace	—
$FeCO_3$	1.23	1.25	1.47
SiO_2	3.84	1.70	4.00
H_2O	n.d.	—	0.70
Fe_2O_3	0.69	—	—
Al_2O_3	0.98	—	—
Total ..	100.22	99.15	99.67

1.—Black limestone. Cooper's Creek, near the Thomson River copper mine. Analyst, N. R. Junner.

2 and 3.—Tyers River limestone (*vide* Progres Report, Victorian Geol. Survey, 1876).

(*b*) *Panenka Beds.*—These beds are best developed between the Jordan River and Yarra track. They consist chiefly of soft yellow fossiliferous mudstones and shales. They underlie the basal grit of the Walhalla beds, and apparently overlie directly the Upper Ordovician strata.

The following are some of the fossils collected from these beds by Mr. O. A. L. Whitelaw :—*Panenka gippslandica* M'Coy sp., *Tentaculites matlockiensis* Chapman, *Styliola fissurella* J. Hall, var. *multistriata* Chapm., *Cycloceras tenuiannulatum* M'Coy, var. *australis* Chapm., *Ceratiocaris* sp., *Paracardium*, and *Pleurotomaria* (No. 8, p. 226).

(*c*) *Monograptus Beds.*—Beds containing abundant Monograptus outcrop in and adjoining the valleys of the Thomson River near Mount Easton and Aberfeldy, and in the Big River near Enoch's Point.

Near Mount Easton they directly underlie the basal grit of the Walhalla beds and rest on the highly-cleaved fossiliferous black slates of Upper Ordovician age. The same sequence occurs near Enoch's Point (*vide* sections, fig. 2).

Lithologically, these beds are in the main black and greyish-green shales and mudstones, with some soft yellow and white and hard black micaceous sandstone.

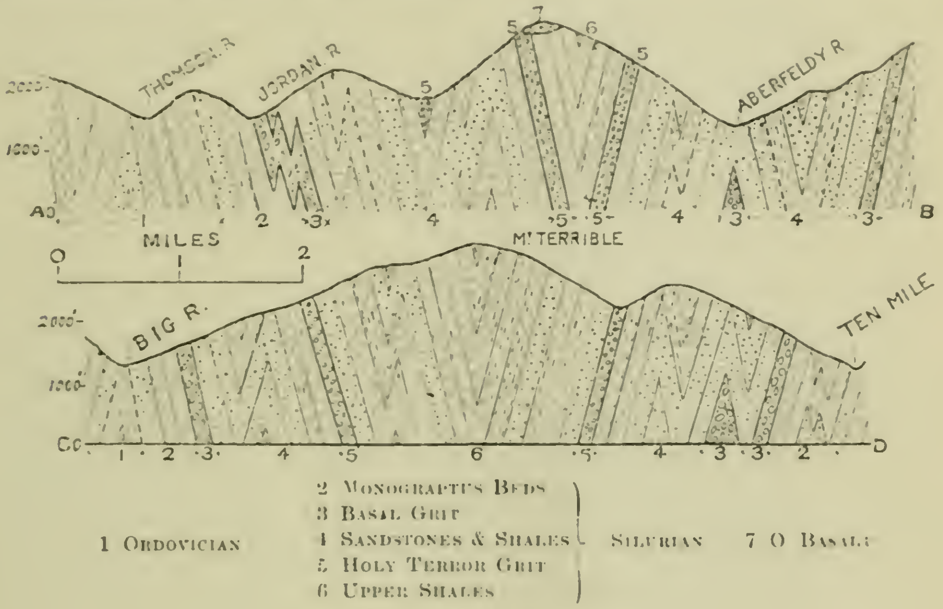

Fig. 2.

Sections along lines A B and C D on geological locality map.

(The Upper Ordovician and Monograptus beds in and adjoining the valley of the Big River near Enoch's Point were discovered by Mr. O. A. L. Whitelaw in his survey of this area).

Horizontal Scale 1 in. = 2 miles.

Monograptus cf. dubius is abundant in certain bands of black shale, but other fossils are rare. Occasional worm tracks and remains of crinoids occur in places in these beds.

(*d.*) *Store Point–Mount Useful Beds.*—Below the eastern basal conglomerate of the Walhalla beds near Store Point and Mount Useful are certain beds which, in the absence of fossils, are included provisionally with the Lower Silurian. Lithologically, they differ essentially from the other sediments of this belt. The uppermost beds consist chiefly of thin-bedded highly-cleaved black slates. Underlying these beds, east of Store Point and near Mount Useful, are bands of purple shales and mudstones associated with green and white sandstones and quartzites, which are possibly of terrestrial origin.

According to Mr. O. A. L. Whitelaw (No. 57, p. 8), these beds overlie the fossiliferous strata of Upper Ordovician age, and, as indicated above, they underlie the basal grit of the Walhalla beds. Patient search by members of the Geological Survey for fossils in these beds has yielded negative results, with the exception of some fucoids (?).

Locally, these beds are highly crumpled and contorted, and crush conglomerates have been developed in places.

B.—DYKES OF DEVONIAN AGE.

(1) *General Remarks.*—Dyke rocks of Devonian age are very abundant throughout this region. They reach their maximum development in the central geosynclinal area between the western basal grit of the Walhalla beds and a line passing approximately through Jamieson, Ten-Mile, Johnson's Hill (near Wood's Point), Toombon, and the Eureka mine (near Walhalla). East of this line no dykes of this age are known. Between the Baw Baw, Mount Arnold, and Mount Torbrech granodiorite massifs and the western basal grit above mentioned, similar dykes are common in certain places, but with few exceptions they have yielded little gold. Furthermore, the dykes are not uniformly developed throughout the central belt, whose limits have been outlined above. They are most prevalent in the troughs of the geosyncline where the intensity of folding and fracturing has been greatest, as at Walhalla, near Toombon, Wood's Point, Gaffney's Creek, and Mount Terrible, between Enoch's Point and Ten-Mile. The geological and locality sketch map illustrates these relations very clearly.

In general, the dykes conform closely in strike and dip to the sedimentary rocks, and without doubt their intrusion was a concomitant of the folding of these sediments.

Normally, the dykes are narrow, averaging about 6 ft. in width, but occasionally they expand into lenticular bulges or expansions. The following figures are the approximate maximum dimensions of some of these expansions :—

Morning Star	1700 ft. x 280 ft.
Bald Hills dyke, near Matlock ..	950 ft. x 300 ft.
Toombon	900 ft. x 300 ft.
New Loch Fyne	700 ft. x 280 ft.
Luck's All	800 ft. x 200 ft.
Eldorado	640 ft. x 300 ft.

On the other hand, the Tubal Cain intrusion, as pointed out by W. Baragwanath (No. 2, p. 269), appears to be a volcanic neck or plug. It is roughly circular in plan—850 ft. x 750 ft.—has approximately vertical sides, and is composed largely of a rock of basaltic composition. It is quite distinct, however, from the basaltic necks of Tertiary age which are described below.

Considerable variation is evident in the texture and composition of the dyke expansions. Normally their borders are finer-grained and more basic than their interiors.

This is particularly well exemplified in the Morning Star dyke, where augite, ilmenite, and apatite are more concentrated in the finer-grained marginal *facies* ; and in a lesser degree in the New Loch Fyne, Eldorado, and Luck's All dykes. The central portion of the Tubal Cain intrusion consists of a medium to coarse-grained gabbro-porphyrite which grades into a marginal fine-grained black basalt. Many of the narrow dykes exhibit chilled margins.

All these intrusions are truly hypabyssal, and their present exposed portions appear to have consolidated under no great thickness of overburden.

The rocks of the dyke bulges, although frequently resembling plutonic types in hand specimens, under the microscope invariably show a ground-mass of some sort. In the narrow dykes a porphyritic structure is the rule, and vesicles and a devitrified glassy base are present in some cases.

Thermal metamorphism of the surrounding strata is usually slight. Induration of the sediments in close vicinity to the larger dykes is common—*e.g.*, A 1, Morning Star, New Loch Fyne, &c.—but this alteration appears to be confined to a hydrothermal alteration—carbonation, sericitization, silicification, and pyritization—by solutions and vapours connected with the intrusion of the dykes and quartz-veins. Such alteration rarely extends for greater distances than 30 ft. from the dykes. Horses of sedimentary rocks included in the dykes show no signs of assimilation.

Coarsely-crystallized pegmatite veins are uncommon, but aplite veins and streaks of quartz and felspar not infrequently intersect the rocks of the dyke bulges.

(2) *Age of the Dykes.*—Concisely, the evidence for the Devonian age of these dykes is as follows :—

1. They are intrusive into the highest beds of the Upper Silurian.
2. They are overlain by the basal conglomerates of the Lower Carboniferous beds near Mansfield. These conglomerates in places carry a little alluvial gold which, presumably, has been derived from the dykes and reefs in the underlying Silurian rocks.
3. The writer knows of no cases of these dykes being intrusive into the Baw-Baw, Mount Arnold, and Mount Torbrech granodiorite massifs, although they occur in the contact rocks on their northern, eastern and western flanks. The granodiorite in turn is overlain, near Buxton, by the Cathedral sandstones which lithologically resemble closely the Mansfield beds of Lower Carboniferous age.

Hence it is seen that the age of these dykes is post-Upper Silurian and pre-Lower Carboniferous, and therefore Devonian.

(3) *Magmatic Differentiation.*—It is believed that these dyke rocks are all genetically related. The following evidence is advanced in support of this contention :—

Occurrence.—There exists a remarkable uniformity in the structural features of these intrusions. Narrow dykes, with elliptical expansions conforming closely to the strike of the sediments, sometimes for considerable distances, are the rule. As mentioned previously, the majority of the dykes occur within the geosynclinal area, and they are more abundant in the trough of the geosyncline than elsewhere.

Petrological Similarities.—(*a*) Brown hornblende was an original constituent of almost all these rocks. It is absent in the acid dykes (quartz porphyries) from Brohan's Reef, Thomson River and St. Lawrence dykes, and apparently in the Tubal Cain dyke.

(*b*) Ilmenite is another characteristic mineral of these rocks. Its relative abundance in some of them is reflected in their high percentages of TiO_2.

(*c*) Interstitial micrographic and cryptographic intergrowths of quartz and felspar are the rule in the coarser-grained rocks of the dyke expansions. The Aberfeldy peridotite and the acid dykes above mentioned do not show this structure.

Metasomatic Alteration.—Almost without exception these rocks have been metasomatically altered in a greater or lesser degree. Three main types of alteration are recognizable—

(*a*) Late magmatic alteration.
(*b*) Propylitization.
(*c*) Hydrothermal alteration by the vein-waters.

The chemical and mineralogical changes brought about by these alterations are remarkably uniform in character throughout the belt, suggesting strongly a common origin for the waters or gases responsible for the alteration. Furthermore, evidence will be adduced in the sequel to show that these waters and the dykes are of congeneric origin.

The widespread intimate association of auriferous quartz-veins with these intrusions further supports the idea of consanguinity.

The available evidence is insufficient, however, to discuss with any degree of positiveness the nature of the original magma and the *modus operandi* of its differentiation. It is probable that these dykes are related to the granodiorite massifs of Baw-Baw, &c., but in what way is not clear.

The constant appearance on Victorian goldfields of rocks of dioritic composition and of quartz porphyries, not far removed geographically or in age from granodioritic intrusions, is suggestive, in the writer's opinion, of some genetic relationship between them.

The general order of intrusion of these dykes is fairly clear. Broadly, the order appears to be one of increasing acidity. We find acid dykes, aplites, granophyres, and quartz-feldspar veins cutting many of the basic and ultra-basic rocks. The ultra-basic copper-bearing New Loch Fyne dyke has been altered along its contact by the normal diorite-porphyrite dyke. Furthermore, the residual magmatic extracts which have been squeezed through these rocks, causing the alterations mentioned above, appear to become progressively more acid. On the other hand, no case is known of a basic dyke of Devonian age cutting a more acid one.

C.—TERTIARY BASALTS.

Several small pipes of older basalt have been located by Mr. Baragwanath and Mr. Whitelaw in their surveys of this belt. Basalt-flows of the same age occur at Mount Lookout, at Moondarra, near Walhalla, and at numerous places on the Thomson–Aberfeldy divide between Aberfeldy and Beardmore's. As previously suggested, these last-named flows were probably once continuous, and came from Mount Lookout, Aberfeldy.

Petrologically, these rocks are normal olivine basalt, and call for no comment.* The pipe on the Reefton track, about 2 miles west of the junction of the two branches of the Thomson River, is interesting, inasmuch as it contains numerous inclusions of ultrabasic rocks—peridotites and pyroxenites—which are moderately rich in the spinels, pleonaste and picotite and chromite (?).

D.—STRUCTURAL FEATURES.

(1) *Folding.*—The structure of this belt is that of a corrugated geosyncline—the Walhalla geosyncline—between two geanticlines, the Matlock anticline on the west and the Black River–Mt. Selma anticline on the eastern flank. In general the beds are closely folded, and dips rarely become less than 50°. In the northern portion of this belt, between Jamieson and Gaffney's Creek, rapid alternation occurs in the direction of dip in places. In Hickey's

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* Petrological descriptions of some of these rocks are embodied in the papers by Dr. A. W. Howitt (No 25), Professor J. W. Gregory (No 17) and Professor E. W. Skeats (No 43).

road cutting, on the coach road between Kevington and Ten-Mile, ten anticlines and ten synclines are exposed in a width of section of about 150 yd.

The average strike of the sediments is N.N.W. As will be seen from the geological sketch map (Plate I.), the Silurian strata bend round the Baw-Baw granodiorite massif, the intrusion of which appears to have caused this variation in the direction of the strike. It might be suggested that this curvature is due to the pitch of the beds, but this is not likely, as beds of the same horizon—*e.g.*, Monograptus slates and the western fossiliferous grit—can be traced on the surface for considerable distances, and there is no field evidence of any regional pitch.

(2) *Faulting.*—The faults in this belt may be subdivided broadly into the following types, viz. :—

(A) Strike-faults.
    (a) Dip slip faults.
    (b) Strike slip faults.
(B) Oblique faults.
(C) Horizontal faults.

Faults of class (A) greatly outnumber those of the other classes. The bulk of the strike-faults appear to be connected with the folding of the strata, and they are frequently occupied by auriferous quartz-veins, and are therefore of considerable economic importance. Their recognition is often difficult, unless, as is often the case, they intersect and displace dykes.

Faulting of this nature appears to have taken place on an extensive scale before and immediately after the intrusion of the dykes. Strike-faults of later date than the formation of the auriferous quartz-veins are not common.

In dip slip faults the component of the movement in the direction of the dip of the fault has been greater than the component in the direction of the strike. Numerous examples of such faults have been seen in the mines near Enoch's Point, Kevington, Ten-Mile, and Gaffney's Creek. In nearly all cases they intersect and displace dykes. The displacement caused by these faults is rarely greater than 20 ft., but in one or two cases displacements of 40 or 50 ft. have been noted.

In strike slip faults the component of the slip along the fault-plane in the direction of the strike is greater than in the direction of the dip. Faults of this nature are fairly numerous, but, as in the former case, their recognition is difficult apart from some indicator such as a dyke or quartz reef. In many cases, as at the Blue Ribbon mine near Ten-Mile, Victor's Quartz, and at Claxton's Reef, near Toombon, these faults displace dykes, and quartz reefs have formed along them. The horizontal displacement at the Blue Ribbon mine, according to Whitelaw (No. 57, p. 13), is 158 ft.

Oblique faults or cross-courses are far less numerous than strike faults, and, unlike the latter, they do not appear to be connected with the folding of the strata, and are mostly of later age than the quartz reefs.

Many, if not most, of the reefs within the dyke expansions occur in faults which often displace the dykes for considerable distances. For instance, the famous Age of Progress reef in the Morning Star dyke appears to be filling a reversed strike-fault which displaces the dyke about 40 ft. Again, the large reef seen in the 600-ft. level in the same mine occurs in a similar fault which has displaced the dyke about 50 ft., and many other reefs in this dyke occupy faults. In the A1 and New Loch Fyne mines many of the reefs occur in faults which have displaced the dykes for varying distances, and, according to Mr. Baragwanath (No. 3, p. 42), the quartz reefs in the Eureka dyke, near Walhalla, occupy fault-planes. Faults later than the main reefs are rare in these dyke expansions.

E.—TYPES OF QUARTZ REEFS.

The reefs of this belt may be classified as follows:—

(1) Reefs occurring in or along walls of dykes.
(2) Reefs occupying fault-planes, intersecting or in close association with dykes.
(3) Bedded reefs.
(4) Fault-reefs apparently not associated with dykes.
(5) Gash veins and stockworks in sedimentary rocks.

From an economic standpoint the first two classes have proved to be most important.

(1) *Reefs Occurring in or along Walls of Dykes.*—The dyke reefs have more extensive development, and have been worked to a much greater degree than any of the other types. They occur in various ways—

(*a*) As relatively flat veins or "floors," dipping at small angles from wall to wall of the dyke, and sometimes continuing out into the surrounding strata. Particularly fine examples of this type can be seen in many of the narrow dykes—*e.g.*, Waverly, May Moon, Georgia, Dempsey's, Excelsior, Hunt's, &c. In the majority of cases the reefs stop short at the dyke walls. More commonly the reefs dip at angles between 30° and 50° from wall to wall, as in the A 1, Morning Star, New Loch Fyne, Eldorado, Luck's All, and Eureka dykes. In the A 1 and Morning Star mines, and less commonly in the New Loch Fyne, the reefs dip alternately in opposite directions, as is seen in figs. 3 and 4.

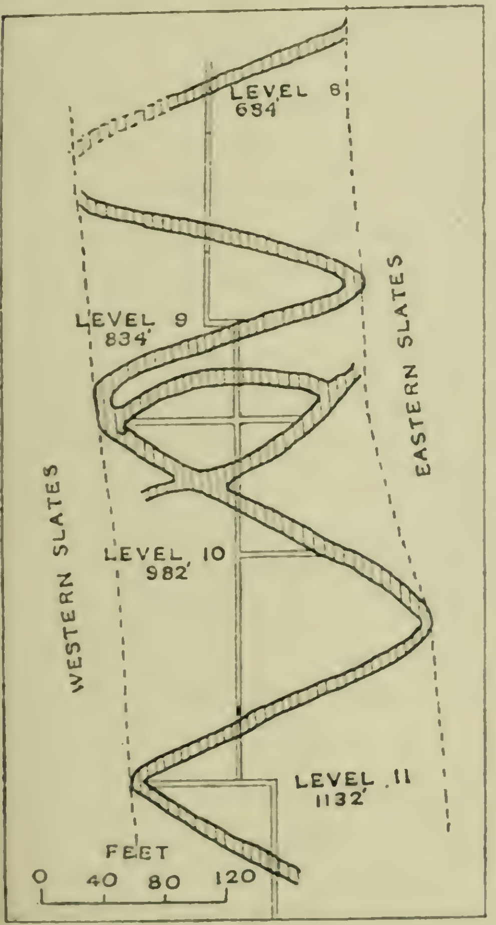

Fig. 3.

Transverse section through the A 1 Gold Mine showing arrangement of quartz reefs.

Reduced from section by Mr. P. D. M'Kenzie, Surveyor to the A 1 mine.

(*b*) Transversely from wall to wall, and dipping at angles approaching the vertical. Reefs of this type are occasionally met with in some mines—*e.g.*, Working Miners', Kevington.

(c) Steeply-dipping longitudinal reefs.—These are not uncommon, but are rarely payably auriferous, except occasionally at or in close vicinity to their junctions with flat veins, as at the Little Comet mine. At the A 1 mine reefs of this sort sometimes fill fault-fissures which intersect and displace the main floors for a few inches.

At the New Loch Fyne mine, narrow, steeply-dipping, poorly-auriferous veins, which strike approximately north and south, and apparently occupy fault-planes, intersect the main floors of quartz. They appear in some cases to be the feeders for the main reefs.

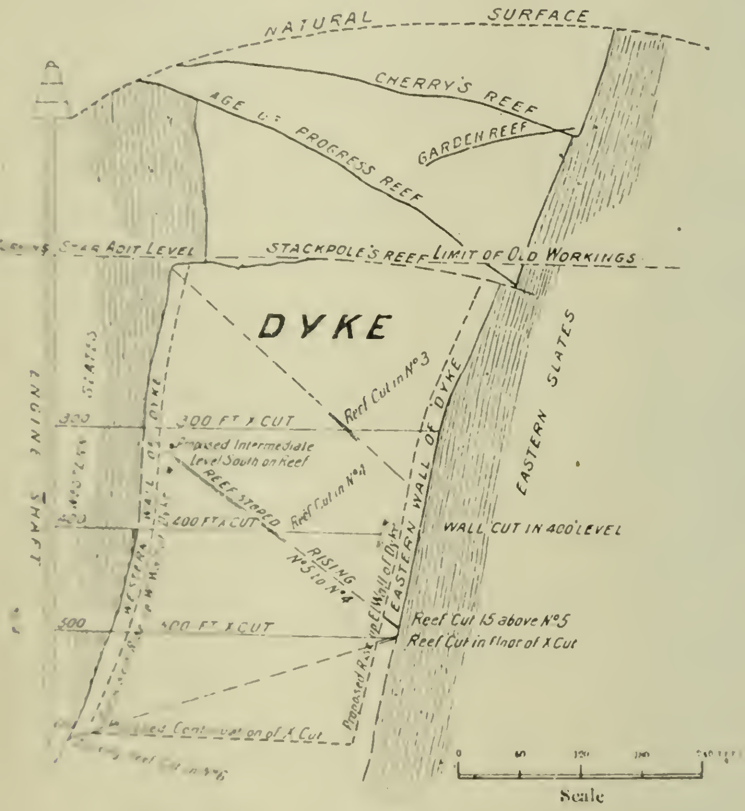

FIG. 4.

TRANSVERSE SECTION THROUGH THE NEW ENGINE SHAFT, MORNING STAR DYKE, WOOD'S POINT.

Showing arrangement of quartz reefs within the dyke. Reproduced from Mr. O. A. L. Whitelaw's section in the prospectus of the Morning Star G.M. Co.

(*d*) Reefs along dyke walls.—Reefs of this type have been worked at the Domino mine, near Jamieson, Brohan's reef, and the Bristol reef, near Gaffney's Creek. They have yielded little gold.

(e) Stockworks.—In many of the narrow dykes—*e.g.*, Rose of Denmark and Working Miners'—and in some of the larger ones the quartz veins ramify through the rocks in all directions, forming typical stockworks. In such cases the whole of the dyke is crushed if within the shoot of gold.

(2) *Reefs Occupying Fault-Planes, &c.*—Fault reefs which intersect and displace dykes occur in numerous places between Kevington, Enoch's Point, and Gaffney's Creek, and near Aberfeldy. They have been worked with some success at the Alabama, Home Rule, Victor's Quartz, and Toombon mines, and also at Alexandra, which is outside this belt. Almost without exception they are richest at the intersections with the dykes, and are usually enlarged in this vicinity.

Cohen's, Lily, Harbinger, and All Nations are examples of reefs within fault-fissures in close association with dykes.

(3) *Bedded Reefs.*—Mr. Whitelaw (No. 57, p. 20) has shown that the reef worked at the Royal Standard mine was an inverted saddle reef, and, according to Mr. Dunn (No. 13, p. 42), some of the reefs worked at the United Gleeson's, Star of the West, and Blue Ribbon mines, near Ten-Mile, were of a similar type. Mr. W. Baragwanath informs me that a saddle reef was worked at the White Star mine near Mount Useful.

Diagrammatic illustrations of bedded saddle and inverted saddle reefs on a small scale can be seen in Hickey's road cutting, near Ten-Mile, and at Walhalla. In each case they are closely associated with faults.

(4) *Fault Reefs Apparently not Associated with Dykes.*—A narrow belt lacking in dykes and containing some important auriferous reefs extends from near Knockwood on the north to Store Point and Fulton's Creek at the south end. The reefs in this zone mostly occupy faults which conform closely with the adjoining strata. Bedded reefs have been worked at the Royal Standard and White Star mines, and also at Store Point.

These reefs are generally well laminated and highly mineralized, particularly so at Store Point, where considerable amounts of chalcopyrite, galena, arsenopyrite, and pyrite are present in the veins. Stibnite also occurs in these reefs at the Leviathan, Leichhardt, and Royal Standard mines.

The most productive mines in this belt have been the Leviathan, Royal Standard, Crinoline, Bismarck, and Gippsland Consols.

(5) *Gash-Veins and Stockworks in Sedimentary Rocks.*—Reefs of this type are relatively common in the central dyke belt. They are best developed in thick bands of sandstone, in which they occur either as more or less flat floors which normally end abruptly at the walls of the sandstone bed, or as stockwork formations. Frequently they are seen to be fed by small bedded fault-veins. Reefs of this kind were often very rich near the surface—*e.g.*, Never Mind, near Wood's Point, which is reported to have yielded about 7000 ozs. of gold from surface to a depth of 100 ft.—but in no case have they proved payable below water-level.

3.—PETROLOGY.

A.—PREVIOUS LITERATURE.

Professor E. W. Skeats (No. 43), in an appendix to Mr. O. A. L. Whitelaw's report on the Wood's Point district, has summarized the results of previous workers on the petrology of the auriferous dyke rocks of this area. He also examined thin sections of many of the dykes and described in detail the microscopical characters of the New Loch Fyne dyke. He speaks of these rocks as propylitized diorites and hornblende porphyrites, and suggests that they are probably apophyses of buried granodiorite masses, probably of Lower Devonian age. Professor Skeats agrees in the main with the present writer's conclusion (No. 28, p. 128) that the regional propylitization of the rocks is independent and earlier than the introduction of the gold-bearing vein solutions. He furthermore shows that Professor Gregory's use of the term "propylitization" was a somewhat loose one, and states that all the dyke rocks described by Professor Gregory should be regarded as propylitized, and not simply the more-altered rocks to which he restricted the term, and, further, that some of the rocks regarded by the latter as propylitized diorites had suffered not only propylitization but also hydrothermal alteration by the vein-solutions.

Professor Skeats described the New Loch Fyne dyke as a propylitized quartz hornblende diorite consisting chiefly of chloritized brown hornblende crystals, porphyritic zoned plagioclase—oligoclase to labradorite—ilmenite, and a little (probably secondary) interstitial quartz and orthoclase. The micrographic intergrowth of quartz and feldspar he regards as probably one of the effects of propylitization on the ground-mass of the rock.

Professor Skeats also draws attention to the remarkable resemblance between the field occurrence and petrological characters of the dyke rocks from the New Loch Fyne mine and those from Wood's Point and Gaffney's Creek.

Apart from the above-mentioned petrological examinations of certain of the dykes from the Wood's Point district by Mr. Mennell and Professors Gregory and Skeats, the only other rocks whose microscopical characters have been studied are certain ones from the Walhalla district.

The late Dr. A. W. Howitt (No. 25) described samples of the dykes from the Long Tunnel, Long Tunnel Extended, Great South Long Tunnel, Longfellow's, and the Walhalla Proprietary mines, as quartz mica diorites which sometimes contain hornblende. The Thomson River copper mine dyke he determined to be a hornblende diorite with a little quartz, and the Tubal Cain rock an augite bearing mica and hornblende diorite. A dyke from the locality marked Note 24 near the Eureka mine on the geological plan of Walhalla he described as a normal olivine basalt.

B.—DETAILED DESCRIPTION.

The Devonian dyke rocks of this belt may be classified as follows :—

(*a*) Quartz-feldspar porphyries, granophyres, and aplites.
(*b*) Diorite porphyrites.
(*c*) Lamprophyres.
(*d*) Gabbro porphyrites and basalts.
(*e*) Ultra-basic rocks—peridotite and perknites.

Auriferous quartz-veins are associated with all these rocks, with the exception of class (*e*), but by far the most economically important reefs occur in or in close relation to rocks of classes (*b*) and (*c*).

(*a*) *Quartz-Feldspar Porphyries, &c.*—Rocks of quartz-feldspar porphyry type occur in a few places in the southern portion of the belt. For the exact location of some of these rocks and for specimens of same the writer is indebted to Mr. W. Baragwanath.

Quartz-feldspar porphyry, 50 ft. wide, junction of Jordan and Thomson Rivers.—In hand specimens it is a yellowish-green aphanitic rock, with minute crystals of pyrite and arsenopyrite disseminated through it.

Examined microscopically, it is seen to have consisted originally of porphyritic phenocrysts of feldspar, now almost entirely replaced by sericite and a little pyrite, and smaller ones of biotite and quartz in a microcrystalline ground-mass consisting chiefly of quartz grains and wisps of sericitic mica. Ilmenite and apatite are accessories. The biotite has been bleached, and rutile needles have separated out. Pyrite crystals having the form of the pyritohedron replace the biotite in places. The rock has been extensively sericitized, and a little secondary quartz and pyrite have been developed. Carbonates are absent.

No. J3, Sericitized quartz-feldspar porphyry, Brohan's Reef, near Aberfeldy.—This rock consists of idiomorphic phenocrysts of feldspar now entirely sericitized, and occasional corroded phenocrysts of quartz in a crypto-crystalline ground-mass made up chiefly of sericite and finely-divided quartz. A few small laths of bleached and pyritized titaniferous biotite are present. Numerous idiomorphic crystals of pyrite replace the ground-mass. The larger ones are surrounded by fringes of secondary quartz.

Quartz-feldspar porphyry dyke, Waterloo Gully, south-west of Aberfeldy.—This rock consists of greatly sericitized panidiomorphic phenocrysts of orthoclase and subordinate acid plagioclase (albite-oligoclase), prismatic laths of bleached biotite, including abundant rutile and a few corroded pellucid crystals of quartz in a microcrystalline ground-mass made up of quartz grains, microlites of feldspar, and sericite flakes. Zircon and apatite are accessories. One or two vesicles now filled with secondary quartz are present. Dusty sericite is the most abundant secondary mineral. Some pyrite and carbonates are also present.

No. 238, Dyke, Walhalla Proprietary Company. — A holocrystalline rock consisting of abundant phenocrysts of feldspar, panidiomorphic quartz, and bleached biotite, from which rutile, sphene and iron oxides have separated. A little interstitial micropegmatite is distributed through the section, and massive carbonate fills interstices between the quartz and feldspar crystals in places, and in part replaces the quartz. Orthoclase appears to be in excess of plagioclase, which is andesine, but both are much sericitized, and it is difficult to determine their relative proportions. A little pyrite replaces the biotite and feldspar. Nomenclature : Altered quartz-feldspar porphyry.

No. 872, Mines Department Collection, St. Lawrence dyke, Aberfeldy River.—This rock consists for the most part of long prisms of plagioclase (oligoclase) and orthoclase in approximately equal amounts. A little biotite, ilmenite, quartz, and accessory apatite are also present. A micrographic intergrowth of quartz and feldspar can be seen in parts of the section. Carbonates and sericite have been extensively formed, also a little chlorite, and grains of pyrite which replace ilmenite.

Granophyres.—These are acid rocks occurring as dykes and veins, and consisting largely of orthoclase, quartz, and hornblende in a ground-mass which is made up of abundant beautiful micrographic and pseudospherulitic intergrowths of quartz and feldspar. The best known examples from this belt are the Alabama dyke, near Matlock; Raymond's dyke, near Gaffney's Creek; dyke crossing the "r" in "Jericho" on geological and locality sketch map (Plate I.); and a vein in the Eldorado dyke (dioriteporphyrite), near Gaffney's Creek.

The Alabama granophyre is associated with a basic gabbrodiorite or porphyrite, but the field relation between the two types could not be determined.

Quartz-veins occur within all these granophyres, but they have yielded negligible quantities of gold.

Granophyre, Alabama dyke, Matlock.—A thin section of this rock shows phenocrysts of orthoclase, plagioclase, quartz, and abundant pseudomorphs after hornblende with a little biotite, all embraced by beautiful interstitial micrographic and pseudo-spherulitic intergrowths of quartz and feldspar. Orthoclase is greatly in excess of plagioclase, which latter is referable to albite-oligoclase. The orthoclase contains occasional microperthitic inclusions of albite and idiomorphic crystals of hornblende. Epidote, sericite, and carbonates replace it in part. Generally the intergrowths of quartz and feldspar occur as fringes to the phenocrysts of orthoclase and plagioclase, but sometimes they merge into one another. Some splendid pseudomorphs of carbonates and microspherulitic chlorite after idiomorphic hornblende are seen in the section. Grains of leucoxene and sphene have separated out from the hornblende on its alteration, and these have been concentrated for the most part along the margins of the crystals. A little secondary quartz has been formed at the same time. Massive interstitial carbonate is distributed through the section. It is distinct from the carbonate replacing the hornblende, &c., and is essentially contemporaneous with the granophyric intergrowths of quartz and feldspar, and in one place in the section is apparently intergrown with quartz. Microspherulitic chlorite is common. It occurs in two ways—

(1) Massive, marginal to carbonates, and in part replacing them.

(2) In granular form, replacing hornblende.

A feature of interest in this rock is the relative abundance of a pleochroic—colourless to yellow—mineral, in radial and stellate aggregates, which often have a nucleus of chlorite or carbonate. Viewed under the high power, it appears as pointed prisms which have a higher refractive index than apatite and all sections of carbonate. Under crossed nicols it shows bright polarization colours of second or third order, and extinguishes parallel to the length of the prisms. To determine the precise optical characters of the mineral, some of the rock was crushed to pass a 1 mm. sieve, and the heavy and light portions were separated by bromoform, G. = 2.80. The heavy residue was dried and the abundant ilmenite and leucoxene were separated by an electromagnet. The remaining material was hand-picked under the microscope, and numerous grains of the doubtful mineral were collected. Determination of its refractive index showed that its R.I. in all cases was greater than R.I. monobromonapthalene = 1.658. Some of the grains were mounted on a glass slip and viewed under convergent polarized light. They showed a central straight bar, which curved very slightly on rotation of the stage, proving the mineral to have a large axial angle. Determination of its sign showed that it is *—ve*. The above-mentioned properties agree closely with those of epidote. Interlaminated with the epidote in places are prisms of a colourless mineral having a lower refractive index than the epidote, and exhibiting ultra blue polarization colours. It is therefore zoisite.

Granophyre, Raymond's Dyke, near Hunt's mine, Gaffney's Creek.—A thin section of this rock is composed chiefly of large relatively fresh phenocrysts of orthoclase feldspar with subordinate plagioclase (oligoclase), long laths of biotite, idiomorphic phenocrysts of hornblende, and irregular-shaped grains of quartz in a ground-mass made up chiefly of microspherulitic and micrographic intergrowths of quartz and feldspar, which generally have a nucleus of sericitized feldspar and quartz. Leucoxene, idiomorphic crystals of sphene, and apatite are accessories. Both the hornblende and the biotite have been entirely replaced. The hornblende exhibits its usual type of alteration to aggregates of pennine and carbonates, with the separation of sphene and rutile. Pennine is the most common alteration-product of the biotite but white mica and carbonates are often developed; rutile has separated out. Abundant dusty carbonates, pennine, sericite, and a little pyrite are secondary minerals.

Granophyre, dyke bulge in Ordovician strata at the "r" in "Jericho" on geological and locality map (Plate I.).—This rock, in thin section, resembles closely the dyke from the Alabama mine, Matlock. It consists of panidiomorphic phenocrysts of hornblende which are bleached, are partially replaced by pennine and a little epidote and large phenocrysts of feldspar, in a ground-mass consisting chiefly of beautiful granophyric intergrowths of quartz and feldspar with a little hornblende and granular secondary quartz. Sphene and apatite are accessories. Orthoclase preponderates over plagioclase, which latter is referable to oligoclase-andesine. The usual alteration-product of the feldspar—namely, sericite—is very rare, but pennine, epidote, sphene, and fairly abundant zoisite replace it. No carbonates are present.

Granophyre vein in diorite porphyrite, lower adit level, Eldorado mine.—This rock consists for the most part of idiomorphic phenocrysts of hornblende and feldspar, which latter is mainly orthoclase, in a granophyric intergrowth of quartz and feldspar. Phenocrysts of quartz are lacking, and, apart from the intergrowth with feldspar, it is very rare in the ground-mass of the rock. One or two large phenocrysts of plagioclase are seen in the section. These give symmetrical extinction angles of 21° and 24° respectively, and have greater refractive index than orthoclase adjoining, and are therefore andesine. Sericite, carbonates, and a little epidote and chlorite replace some of the feldspar, but for the greater part it is remarkably fresh. The hornblende is much less altered than usual, and occurs in idiomorphic crystals which are often included in the feldspar. The granophyric intergrowth normally occurs marginal to feldspar phenocrysts, but in places penetrates and veins the feldspar. Sphene and ilmenite are accessories. Chlorite, sericite, leucoxene, and a little carbonate and pyrite are secondary.

Aplite.—Rocks of this type occur as veins or narrow dykes traversing the more basic rocks.

Section No. 460 of aplite vein traversing the Eureka dyke near Walhalla is characteristic of this type. It is a holocrystalline rock composed of laths of little-altered biotite, prisms of sericitized feldspar which is chiefly albite, and irregular grains of quartz and needles of ilmenite, all apparently intergrown with one another. Rutile needles have separated out from the biotite, and a little pyrrhotite is scattered through the section.

No. 294, aplite vein in basalt, Coronation mine, Tubal Cain dyke.—This is an even-textured medium to fine-grained rock, consisting chiefly of granular pink feldspar and green prisms of augite with some quartz. Microscopically, it consists of greatly chloritized phenocrysts of augite in a mosaic of granular quartz, sericitized and epidotized feldspar—orthoclase slightly exceeds the plagioclase (albite) in amount—ilmenite, white mica, and apatite. The quartz and feldspar exhibit a tendency to graphic intergrowth. The usual hornblende and carbonates are absent from this rock. In addition to chlorite, some serpentine and epidote have developed from the augite.

No. 252, acid vein (aplite) traversing hornblendite, Shamrock dyke, south of Wood's Point.—This rock consists of large panidiomorphic phenocrysts of hornblende and feldspar and occasional ones of quartz, in a ground-mass made up of mosaics of quartz, laths of feldspar, and idiomorphic crystals of hornblende. Ilmenite, sphene, and apatite are accessories, and chlorite, carbonates, sericite, leucoxene, and pyrite are secondary. Tremolitic and actinolitic outgrowths to the brown hornblende phenocrysts are common. They include crystals of ilmenite and pyrite. The feldspar is chiefly orthoclase. It occurs usually in relatively fresh large idiomorphic phenocrysts containing microperthitic inclusions of albite. Carlsbad twinning is usual, but one fine Manebach twin is also present. Minute prisms and grains of a highly refracting mineral, pleochroic—colourless to light pink—extinguishing parallel to the rectangular cleavage planes, and having polarization colours resembling those of calcite, and therefore sphene, are common. Microspherulitic pennine, sericite, and massive carbonates are abundant. The carbonates appear to be essentially contemporaneous with the quartz.

No. 21, aplite vein in Morning Star dyke, west edge, 400-ft. level.—This rock is very highly altered, and determination of its original characters is difficult. Apparently it originally consisted chiefly of granular quartz laths and prisms of sericitized and partly carbonated feldspar—orthoclase and acid plagioclase—and laths of biotite now replaced by pennine and fairly abundant prisms and hypidiomorphic grains of ilmenite and leucoxene. No hornblende is recognizable. Sericite, chlorite, and carbonates are secondary.

(*b*) *Diorite Porphyrites.*—The type rocks of this series are the Morning Star, New Loch Fyne, and Jericho dykes. They have many affinities with the "Markfield" type (diorite granophyre) of the English nomenclature. Economically, these rocks are of considerable importance, as many of the best mines in this belt occur within them. Their petrological features and the nature of the metasomatic alteration undergone by them are furthermore of considerable interest.

The Morning Star rock is the best known and perhaps the most interesting of the series. In hand specimen it is a black and white even-grained rock, consisting chiefly of black hornblende and white feldspar. A little quartz and biotite are also recognizable. Microscopically, the rock is composed of phenocrysts of brown hornblende—penetrated sub-ophitically in places by greatly sericitized laths of plagioclase—frequently having a core of augite and including abundant grains of ilmenite and apatite; panidiomorphic phenocrysts of andesine now extensively sericitized, long laths of biotite and panidiomorphic quartz in a ground-mass made up of hornblende, feldspar laths, granular augite, and a micrographic intergrowth of quartz and feldspar. The relationship between the hornblende and augite is interesting. In some cases the augite is fringed by brown hornblende, which includes much ilmenite, and in others it occurs as an irregular mosaic of grains surrounded by massive hornblende. Ilmenite rarely is included in augite. It seems to be practically all confined to areas of hornblende.

During the consolidation of the rock it was permeated by residual siliceous and alkaline carbonate extracts released by the magma, with the result that the interstices in the rock were filled with quartz, micrographic intergrowths of quartz and feldspar, albite, and carbonates. Actinolitic and tremolitic outgrowths to the hornblende were formed at the same time. Large quartz crystals, which include clear crystals of albite, occur in optical continuity with the quartz of the intergrowths. The massive carbonate appears to be contemporaneous with the quartz.

As a result of a slightly later phase of this alteration, chlorite, serpentine, epidote, and sphene were formed from the hornblende and biotite, leucoxene was developed from ilmenite, and the feldspars were chloritized and sericitized. These minerals are the ones characteristic of the type of alteration spoken of as propylitization.

At a still later period the rock was fractured and penetrated by veinlets of quartz and carbonates.

Specimen analyzed, 10 ft. from Cherry's reef, Hope adit level, Morning Star dyke.—Augite and biotite are less common than in the preceding rock. However, numerous kernels of augite occur surrounded by patches of serpentine and microspherulitic chlorite, which apparently represent replaced augite. The feldspars are partially sericitized, and a little pyrite replaces some of leucoxene. Interstitial micropegmatite is fairly abundant, and generally has a nucleus of highly altered plagioclase (? andesine). Apatite is common. An analysis of this rock is given on p. 188.

New Loch Fyne dyke, No. 5 adit level.—This rock consists in thin section of porphyritic phenocrysts of panidiomorphic hornblende and some cloudy plagioclase and secondary quartz in a ground-mass of feldspar laths and granules of quartz, hornblende, ilmenite, and apatite. A little interstitial micropegmatite occurs in places. Coarse carbonate, chlorite (pennine), muscovite, sericite, leucoxene, albite, quartz, and pyrite are secondary minerals. The hornblende is the usual brown variety, with tremolitic and actinolitic outgrowths, and includes plagioclase laths and ilmenite, and often is sub-ophitically penetrated by the feldspar. It appears to have separated from the magma after the ilmenite and andesine. Augite is rare or absent. Two generations of feldspar are present. The first type is highly sericitized and zoned plagioclase (? andesine). The second type is in the form of relatively fresh laths of plagioclase having a refractive index less than quartz and showing symmetrical extinction angles of 16° from the twin lamellæ, proving it to be albite. It appears to be secondary and to be formed at the same time as the micropegmatite. Orthoclase is uncommon. It occasionally includes microperthitic albite. Many of the quartz-phenocrysts are in optical continuity with the micropegmatite, and both are of later origin than the main consolidation of the rock. Ilmenite is largely altered to leucoxene.

No. 100, Jericho dyke, near Jordan River, Jericho.—It is an even-textured melanocratic rock composed for the most part of black plates and prisms of hornblende and occasional feldspar phenocrysts. A little pyrite occurs disseminated through the rock.

Under the microscope it consists of abundant panidiomorphic phenocrysts of hornblende—partially bleached and converted into actinolite—including micropœcilitically granules of augite, feldspar, and apatite—and a few phenocrysts of clear albite and quartz in a ground-mass consisting of granular augite, euhedral hornblende and a little ilmenite, interstitial quartz, and feldspar. The two latter minerals are occasionally intergrown with one another. A little pennine and massive carbonate and a few euhedral pyrite crystals have been formed, but on the whole the rock is very free from alteration. The original rock consisted entirely of hornblende and augite, with a little plagioclase feldspar. A more acid residuum from the magma attacked the rock during cooling, with the development of quartz and albite and a little carbonate.

No. 65, diorite porphyrite dyke, near Franklin mine, south of Wood's Point.—This rock is composed of large hypidiomorphic phenocrysts of brown-green hornblende in which x and y = light brown and z = deep greenish-brown, prisms of clear feldspar, predominantly albite, which surrounds and includes some of the hornblende, and pseudomorphs of sericitic mica after phenocrysts of feldspar of doubtful nature, in a ground-mass made up of idiomorphic hornblende, clear feldspar laths, and a little quartz—the bulk of the latter being in the form of a granophyric intergrowth with the feldspar. A little leucoxene and idiomorphic sphene replace the ilmenite. A moderate amount of a colourless or slightly yellow mineral in stellate and radial aggregates is distributed through the section. It is apparently non-pleochroic; its polarization colours are less than those of hornblende, and it shows straight extinction. It is probably anthophyllite.

Wallaby dyke, Gaffney's Creek.—This is a rock of the normal Morning Star type. The hornblende is the usual brown variety, highly chloritized in places, and including much skeletal ilmenite and leucoxene. Pyrites replaces some of the ilmenite. The bulk of the feldspar is highly sericitized. Some of it has a refractive index less than quartz, and gives symmetrical extinction angles of 17°, and is therefore albite, but some orthoclase is also present. Pellucid quartz and micropegmatite are fairly common.

Quartz diorite porphyrite, Eureka dyke, Walhalla.—This rock is composed of idiomorphic phenocrysts of chloritized brown hornblende, prisms of greatly altered feldspar, and some clear quartz in a ground-mass of feldspar laths, granular quartz, and hornblende. Ilmenite and apatite are accessories. Secondary minerals are chlorite, sericite, kaolin, and a little carbonate and pyrite, which latter mineral replaces ilmenite for the most part.

No. 241, Walhalla Proprietary Company dyke, lower adit level.—This is a rock of the Morning Star type, consisting of panidiomorphic phenocrysts of brown hornblende greatly altered to chlorite and epidote with separation of rutile or sphene, columnar crystals of greatly sericitized, kaolinized, and chloritized plagioclase, referable to albite where its characters are determinate, and clear grains of quartz in a ground-mass made up of augite grains, hornblende, plagioclase laths, and a micropegmatitic intergrowth of quartz and feldspar. Ilmenite and a few large crystals of apatite are accessories. The former, for the most part, occurs included in hornblende, and is usually altered to leucoxene. Nomenclature: Quartz diorite porphyrite.

Diorite porphyrite, Thomson River copper mine, near Walhalla.—Variation occurs in this intrusion from the normal diorite porphyrite to a melanocratic rock composed almost entirely of hornblende and a little augite. The normal rock, examined microscopically, consists of abundant panidiomorphic phenocrysts of brown hornblende, a small amount of colourless augite, and isolated phenocrysts of clear orthoclase and albite in a matrix of hornblende, augite, feldspar, and interstitial quartz and micropegmatite. Much of the hornblende is converted marginally into actinolite, and the usual tremolitic outgrowths are common.

Certain basal sections of the hornblende exhibit the form (100), and are therefore anomalous. Inclusions of augite, ilmenite, leucoxene, apatite and feldspar are present in the hornblende. The augite occurs in granular form, and rarely as phenocrysts. Plagioclase, which is albite or oligoclase, occurs as hypidiomorphic phenocrysts which sometimes exhibit both pericline and albite twinning. They include both hornblende and augite, and often appear to be interstitial. A little sericite has developed in places from the feldspar, but on the whole it is remarkably fresh. This rock has suffered very little alteration. Some carbonate and a little chlorite, sericite, pyrrhotite, and pyrite are present in the section.

Specimen No. 220 of the same dyke has suffered greater metasomatic alteration. The breaking down of the hornblende is well seen. Microscopic veinlets of carbonates traverse it, and patches of chlorite have developed in association with them. In the augite the carbonate veinlets are arranged chiefly along the cleavage planes, giving an effect similar to the mesh structure in serpentine after olivine. Sericite and carbonates replace some of the feldspar. Granular and massive copper and iron pyrites, associated intimately with carbonates and secondary quartz, are not uncommon. Some of the quartz and feldspar crystals in this section are in optical continuity with the micropegmatite. It is probable they were all formed at the same time by the squeezing of the residual salic magmatic extracts through the cooling rock.

(c) *Lamprophyres.*—Dykes of this type are of widespread occurrence. Locally—as near Gaffney's Creek, Wood's Point, Matlock, and Jericho—they reach great development. From the surface to a depth of about 100 ft., on an average, and in places to 300 ft., they are so badly weathered that thin sections cannot be cut to determine their petrological characters; consequently, it is generally only when auriferous veins have been worked in them or when they have been intersected in mining operations that unweathered specimens for sectioning can be obtained. In hand specimens they are normally green or grey fine-grained or aphanitic rocks. Petrologically they appear to be mica and hornblende lamprophyres for the most part. When they expand into the so-called dyke-bulges they grade into diorite porphyrites of the Morning Star type. Their ground-mass is usually pilotaxitic or trachytic, and sometimes microcrystalline. In certain cases it is clearly devitrified glass. Vesicles are common in some specimens. Micrographic intergrowths of quartz and feldspar are very rare in these rocks. They are, without exception, more or less altered, and occasionally the alteration has been so severe that their original characters are indeterminate. They generally contain or are associated with quartz-veins which frequently occur in the form of floors or ladder veins.

Hornblende mica lamprophyre (minette), Morning Star dyke, width 6 ft., from immediately south of the dyke expansion.—A thin section of the rock shows that it consisted originally of phenocrysts of brown hornblende, feldspar—predominantly orthoclase—biotite, and a little quartz in a ground-mass made up of prisms of orthoclase, flakes of biotite, and grains of quartz and ilmenite. No hornblende remains, although its characteristic outlines are preserved in pseudomorphs of granular carbonates and chlorite with a little quartz. Carbonates and a little chlorite and quartz replace most of the biotite. A small quantity of euhedral magnetite has separated from the biotite as a result of the alteration. The plagioclase appears to be chiefly albite–oligoclase. Aggregates of sericite, carbonates, and quartz replace it and the orthoclase. Microscopical grains and crystals of pyrite have been freely developed. They display a preference for chlorite areas, and in such cases are euhedral. When replacing leucoxene or ilmenite they are usually in anhedral grains.

No. J40, hornblende lamprophyre (spessartite), Luck's All dyke, Warner's Creek, near Enoch's Point.—An even, medium-grained rock, dark in colour, made up almost entirely of chloritized laths and prisms of feldspar which is chiefly plagioclase andesine type. Quartz is very rare. Micropegmatite is absent. Skeletal crystals of ilmenite partially changed to leucoxene and partially replaced by pyrite are common. Pennine, with a little carbonate, is the usual alteration-product of the hornblende and sericite with occasional crystals of zoisite of the feldspars. The feldspar laths penetrate the hornblende crystals ophitically in parts of the section.

Hornblende lamprophyre, No. 6, 600-ft. level below main adit, Rose of Denmark mine, Gaffney's Creek.—This is a holocrystalline leucocratic rock, consisting of phenocrysts of feldspar, pseudomorphs of chlorite and carbonate after hornblende, and quartz in a greatly altered ground-mass, part of which is in the form of micropegmatite. Plagioclase (albite) predominates over orthoclase. The latter mineral is partially replaced by rhombs of carbonate and flakes of sericite. Abundant leucoxene and a little pyrite replace the ilmenite. Needles of apatite are plentiful.

Specimen No. 5, micaceous dyke (? mica lamprophyre), No. 5 level, Rose of Denmark mine.—No femic minerals remain, and the feldspar is indeterminable owing to extreme sericitization. Numerous long curved flakes of white mica, which include rutile and are greatly replaced by carbonate and elliptical grains of quartz along the cleavage planes, are secondary after original biotite. A moderate amount of granular quartz, partially sericitized and carbonated, occurs in the section.

No. J2, hornblende mica lamprophyre (camptonite), 850-ft. level, A1 mine: analysed specimen.—This rock shows considerable similarity in texture and mineral composition to the Morning Star and New Loch Fyne dykes, but is finer-grained and more altered than the average specimens of these rocks. The hornblende is generally bleached and greatly replaced by pennine and carbonates. Laths of plagioclase are included in the hornblende. Hypidiomorphic prisms and laths of much sericitized feldspar are common. Determination of its specific characters is difficult. It appears to be chiefly acid plagioclase with some orthoclase. An interesting feature of the rock is the presence of abundant hexagonal sections of greyish-black, semi-translucent leucoxene, which replace ilmenite. They are often in skeletal growths showing the characteristic triangular parting. Granular pyrite replaces much of the leucoxene. In only one place in the section is pyrite separated from leucoxene. Some micropegmatite and quartz are also present. Abundant pennine and carbonates and some sericite have been developed at the expense of the original minerals.

Some of the ilmenite and leucoxene were separated from portion of the crushed rock after passing through the 1 mm. sieve by means of bromoform and an electro-magnet, and examined chemically. In addition to FeO and TiO_2 in the ilmenite, a small quantity of MnO was also detected.

A little of the leucoxene was dissolved on a lid of a platinum crucible in 2 or 3 drops of HF, and dilute H_2SO_4 was added in excess. Some of the solution was transferred to a glass slip and evaporated to dryness. Abundant prisms and needles of gypsum were formed, proving the presence of CaO. Reactions were also obtained for FeO, TiO_2, and SiO_2.

No. J17, coarse micaceous dyke, mica hornblende lamprophyre (camptonite), 700-ft. level, A 1 mine.—Hornblende has vanished from this rock. Its place is taken by chlorite, carbonates, and leucoxene. Traces of biotite remain, but the bulk of it has been replaced by carbonates, chlorite, and lenticles of quartz. Sagenitic webs of rutile occur in the altered biotite. The feldspars are replaced in part by chlorite and carbonates, but sericite is uncommon. The usual pennine and carbonates permeate the rock, and occasional grains of pyrite are disseminated through it.

No. J23, aphanitic dyke, stopes below 850-ft. level, in vicinity of rich ore, A 1 mine.—In hand specimen this is a very dense rock, containing numerous patches of a green mineral. Extreme alteration (carbonation and sericitization) mask the characters of the rock. None of the original minerals, with the single exception of ilmenite, remain. Dense aggregates of dusty carbonates, laths of sericite, and a little quartz, pyrite, and chlorite, replace the rock. Veinlets of quartz with some carbonates traverse it.

Mica lamprophyre (? camptonite), Alabama mine, Ten-Mile.—This is a grey-coloured, vesicular, fine-grained rock. Grains of pyrite are disseminated through it. Microscopically it is a fine and even-textured greatly-altered rock, consisting mainly of laths of albite, flakes of white mica secondary after biotite, grains of clear quartz, and abundant disseminated carbonates and sericite. Small patches of chlorite are present, and grains of ilmenite, leucoxene, and pyrite are not uncommon. The vesicles are filled with bladed radiating magnesite and lined with grains of quartz.

Mica lamprophyre, Hunt's dyke, Gaffney's Creek.—As usual, the original characters of the rock are greatly masked by the ubiquitous development of carbonates, sericite, chlorite, and serpentine. Phenocrysts of biotite, apparently, were common in the original rock. They are now almost entirely replaced by chlorite, serpentine, white mica, and "sagenite webs" of rutile. Traces of feldspar crystals preserved in sericite and carbonates are recognizable. Laths of feldspar were apparently abundant in the ground-mass of the rock. The numerous rounded and lenticular vesicles present in the section are filled with quartz and a little carbonate, and lined with sericite.

No. J24, Knowle's dyke, adit level, Enoch's Point.—A grey-coloured aphanitic rock in which no minerals are recognizable in hand specimen. The original rock was fine-grained and non-porphyritic, and consisted essentially of small prismatic crystals of hornblende and laths of feldspar, apparently acid plagioclase. Quartz probably was absent. Dusty and granular carbonates and isotropic pennine replace the hornblende and some of the feldspar. Sericite, pyrite, and quartz are present in small quantity. Nomenclature: Hornblende lamprophyre.

No. J20, vesicular dyke, unknown mine, lower adit level, Enoch's Point.—Originally a very fine-grained vesicular rock, in which porphyritic crystals were absent. Apparently the rock was composed almost entirely of microlitic laths of feldspar and hornblende, and possibly some biotite. Quartz is very rare. Ubiquitous aggregates of dusty carbonate and sericite, with a little chlorite and quartz, now replace the rock. The vesicles are filled with quartz and carbonates.

Other narrow dykes of a similar nature which have been sectioned and examined are the Georgia, Little Comet, Cohen's, Argyle (near Jericho), Excelsior (Blue Jacket Creek), Working Miners' (near Kevington), and one from Camp Creek, a branch of the Aberfeldy River.

(*d*) *Gabbro Porphyrites and Basalts.*—The only rocks of this type known to the writer from this belt occur at the Tubal Cain and Eureka mines, and at locality No. 24 on Mr. Herman's map of the Walhalla district (No. 23). The marginal variation of the

Morning Star dyke is also a quartz gabbro porphyrite. Auriferous quartz-veins, which have yielded a moderate amount of gold, occur in these rocks at the Tubal Cain, Eureka, and Morning Star mines.

The Tubal Cain pipe interiorally is a medium-grained granophyric gabbro porphyrite, but the greater part of the intrusion is composed of a dense black rock of basaltic composition. Occasional aplite dykes and veins of epidote, chlorite, carbonate, and quartz, in addition to the auriferous quartz-reefs, intersect the intrusion.

Specimen No. 229, granophyric quartz gabbro porphyrite, Coronation mine, Tubal Cain dyke.—This is a medium-grained melanocratic rock showing porphyritic crystals of augite and occasional biotite flakes and feldspar in hand specimen. A thin section of the rock is composed of abundant large hypidiomorphic phenocrysts of zoned and simply twinned titaniferous brown augite, ragged prisms of much altered biotite which is penetrated sub-ophitically by plagioclase laths in places, and occasional phenocrysts of greatly-altered feldspar in a ground-mass composed largely of interstitial quartz and feldspar in granophyric intergrowth. Hornblende is absent. Ilmenite and leucoxene are common as inclusions in the biotite. Much of the feldspar is highly sericitized, making determination of its character difficult. It appears to be chiefly labradorite, but a little albite now replaces some of it. One phenocryst of untwinned feldspar appears to be orthoclase. Chlorite and a little epidote replace portion of the augite and biotite, and veinlets of chlorite and carbonates traverse the section.

Gabbro porphyrite, marginal variety of Morning Star dyke, near west wall, 300-ft. level.—This is a holocrystalline, porphyritic considerably-altered rock. It differs from the normal diorite porphyrite in that hornblende is rare and augite plentiful, and in the comparative rarity of quartz and the absence of acid feldspar. The augite is a titaniferous variety, occurring mostly in porphyritic phenocrysts often penetrated ophitically by sericitized laths of plagioclase. It is simply twinned, and has a very low axial angle. Basal sections give a figure which is almost that of a uniaxial mineral, and determination of its sign shows it to be +*ve*. It shows maximum extinction angles of 43° from the prismatic cleavage. The stages in the breakdown of the augite are clearly seen. Interlacing veinlets of carbonates traverse it along cleavage planes and other cracks, and marginally its boundaries are often irregular owing to replacement by carbonates. Brown hornblende occurs in places in the section fringing the augite, and a little biotite is also present. The original feldspar was a zoned basic plagioclase, giving maximum extinction angles of 42° from the twin planes, showing it to be bytownite or anorthite. Abundant sericite and a little chlorite and carbonate replace it. Skeletal crystals of ilmenite are common. Sericite and carbonates have been developed on a grand scale, and replace most of the minerals of the original rock, but chlorite is rare.

Granophyric gabbro porphyrite, marginal variety of Morning Star dyke, east wall, No. 3 (400-ft. level).—This section shows more brown hornblende than the previous one, and, in addition, long wisps of bleached biotite, chlorite, and epidote are fairly common. The feldspar is a zoned acid labradorite, with a little orthoclase. The augite has the usual fringe of hornblende surrounding it, and apparently is not so easily chloritized as the hornblende. Quartz is rare except in granophyric intergrowth with feldspar.

Specimen No. 9, porphyritic basalt, lower adit level, Coronation mine, Tubal Cain dyke; analysis specimen.—In hand specimen this is a dense black rock of basaltic appearance. In thin section it is composed of large hypidiomorphic phenocrysts of brown pleochroic augite in a pilotaxitic ground-mass consisting of sericitized plagioclase laths, chloritized and carbonated granules of augite, a little biotite, and abundant magnetite or ilmenite dust. Veinlets of chlorite and carbonate with a little quartz intersect the rock. The breakdown of the augite has been initiated by veinlets of carbonate which occur along cracks and cleavage planes in the mineral. Patches of chlorite and some dusty carbonates are disseminated through the rock, and a little secondary quartz is also present.

Specimen No. 34, Coronation mine, Walhalla.—It consists of large porphyritic phenocrysts and clusters of crystals of simply and polysynthetically twinned titaniferous augite in a fine-grained mass, consisting of rod-like microlites of greatly sericitized plagioclase near labradorite, traces of biotite, and magnetite dust. Quartz is absent. Chlorite replaces some of the augite.

Specimen No. 223, vein in Tubal Cain dyke.—The vein is composed almost entirely of calcite, chlorite, and epidote in alternate bands, with a little quartz and zoisite. The epidote occurs in hypidiomorphic lemon-yellow crystals, having distinct basal cleavage, and is referable to "pistacite."

An analysis of the Tubal Cain basalt gave the following result. Appended for purpose of comparison is an analysis of an Upper Palæozoic basalt from Mount Wellington.

		1		2
		%		%
SiO_2	..	49.07	..	49.35
Al_2O_3	..	14.88	..	17.61
Fe_2O_3	..	1.64	..	1.50
FeO ..	..	8.27	..	9.72
MgO	..	7.58	..	3.17
CaO ..	..	8.17	..	7.70
K_2O	..	1.05	..	1.56
Na_2O	..	2.87	..	3.10
H_2O+	..	2.21	..	2.56
H_2O-	..	0.48	..	0.65
TiO_2	..	1.46	..	2.83
MnO	..	0.18	..	0.07
FeS_2	..	abs.	..	0.34
P_2O_5	..	tr.	..	—
CO_2 ..	..	2.81	..	—
		100.67	..	100.16

1.—Porphyritic basalt, lower adit level, Coronation mine, Tubal Cain dyke; analyst, N. R. Junner Amer. Class., Auvergnose

2.—Palæozoic basalt, Moroka snow plains, Mount Wellington; analyst, G. Ampht. (No. 48, p. 267.)

Basalt dyke, locality No. 24 on Mr. Herman's map of the Walhalla district.—A tunnel through this dyke, ostensibly with the view of working quartz reefs (which, according to local miners, occurred on the walls of the dyke), shows it to be a little-decomposed dense black basaltic rock. An aplite vein 2 in. in width intersects the dyke in one place, but the writer saw no signs of quartz-veins.

A thin section of this rock, viewed under the microscope, consists of abundant porphyritic hypidiomorphic phenocrysts of light brown titaniferous augite and smaller and less numerous phenocrysts of altered olivine in a fine-grained ground-mass made up of lath-shaped microlites of labradorite, granules of augite, and dusty ilmenite and magnetite. Feldspar phenocrysts are absent. The augite is often twinned and sometimes zoned. It is relatively free from alteration, but a little chlorite locally replaces portion of it. The olivine is more altered. The usual alteration of this mineral is to talc, with separation of hematite. Occasional veinlets of chlorite traverse the section.

Mr. Herman (No. 23, p. 21) has suggested the possibility that this dyke belongs to the period of the so-called Older Volcanic (? Eocene) lava-flows of the district. Quartz-veins are associated with this dyke, and Mr. Herman further suggests the possibility that deposition of quartz may have continued to Tertiary times. However, the petrological characters of this dyke show clearly that it is closely related to the Tubal Cain basalt, which grades into a granophyric gabbro porphyrite intersected by auriferous quartz-veins and associated with the usual metasomatic alteration characteristic of the Devonian igneous rocks of this belt.

Specimen No. 204, upper tunnel, Eureka mine, near Walhalla.—It is composed of numerous phenocrysts of zoned titaniferous augite—pleochroic, pink to delicate-violet colour—in a holocrystalline fine-grained ground-mass, consisting of rod-like microlites of plagioclase feldspar, augite, and ilmenite grains. In part of the section the rock is coarser grained, and some secondary interstitial micropegmatite is present. The feldspar is greatly sericitized and in part chloritized, and determination of its precise characters is therefore difficult. Chlorite (pennine) is fairly common. It replaces some of the augite. A little dusty carbonate is often associated with it. Leucoxene replaces the bulk of the ilmenite. This rock resembles closely the Tubal Cain basalt.

(*e*) *Ultrabasic Rocks* (*Peridotite and Perknites*).—These are heavy, lustrous, black rocks in which the femic minerals hornblende, augite, biotite, and olivine reach their maximum development. They occur as lenticular intrusions up to 300 ft. in width, conforming closely to the strike of the strata.

Petrologically, the following types have been recognized:—Hornblende peridotite, near Aberfeldy; hornblende-pyroxene rocks, from Kelly's copper mine dyke, near Walhalla, and from east of Toombon; hornblendites, from Thomson River copper mine and the Shamrock dyke near Wood's Point.

Except in the case of the Aberfeldy peridotite, a little interstitial quartz and alkaline feldspar are always present in these rocks. Small quantities of magmatic sulphides, pyrrhotite, chalcopyrite, and pyrite occur disseminated through them, but in only one case—namely, the Thomson River copper mine—has the percentage of copper justified the working of them.

Numerous assays carried out from time to time at the Mines Department's laboratories have proved the invariable presence of small amounts of platinum in these rocks. Payable auriferous quartz-veins are not found in them, although a little gold appears to be contained in the sulphide impregnations.

Hornblende peridotite, Frenchman's Gully, near Aberfeldy.—Credit for discovering this rock is due to Mr. W. Baragwanath, who located it during his survey of this area. It is a medium-grained black rock showing phenocrysts of hornblende, biotite, and occasionally augite in hand specimens. Coarser-grained varieties exhibit lustre-mottling, due to inclusions of olivine, augite, and biotite in the hornblende.

Microscopically, the rock is composed of abundant olivine and brown hornblende and lesser amounts of biotite, augite, magnetite, and apatite, together with the secondary minerals talc, serpentine, chlorite, and carbonates. Most of the olivine is present in elliptical and rounded grains, probably due to partial resorption by the magma. Frequently it is altered to colourless talc with the separation of magnetite dust, which diffuses outwards in the form of a cloud to the edges of the original crystals. Much of the olivine, however, has altered to yellow and green serpentine, which sometimes shows the characteristic "mesh" structure. The hornblende occurs in ragged phenocrysts micropœcilitically, including olivine, augite, biotite, and apatite. Apart from tremolitic and actinolitic outgrowths and a partial bleaching, it has suffered little alteration. A little chlorite replaces it in part. The biotite occurs in deep brown to almost colourless plates and prismatic laths. It is much bleached, and some serpentine and chlorite and a little carbonate replace portion of it. Colourless hypidiomorphic crystals of augite are not uncommon. They show little or no alteration. Orthorhombic pyroxenes are absent. One chloritized and kaolinized phenocryst of acid plagioclase is present in this section, but other slides show no sign of feldspar. Of the alteration-products, talc, serpentine, chlorite, and magnetite are most abundant. Some coarse crystals of carbonates associated with magnetite are also present.

An analysis of this rock (No. 1, p. 63) gave the following results, viz. :—

	%
SiO_2	41.43
Al_2O_3	5.92
Fe_2O_3	4.03
FeO	7.46
MgO	27.59
CaO	4.31
K_2O	0.64
Na_2O	0.35
$H_2O +$	6.47
$H_2O -$	0.32
TiO_2	0.60
CO_2	0.38
MnO	0.42
P_2O_5	0.24
SO_3	nil.
Cl	tr.
Cr_2O_3	0.31
NiO	0.03
CoO	tr.
BaO	nil.
Total	100.50

Special features of this analysis are the very low percentages of silica, alumina, and alkalies which are reflected in the rarity of feldspar and the very high percentages of MgO and H_2O, due to the abundance of talc and serpentine derived from the olivine. No chromium mineral was recognized in thin sections of the rock.

Perknites.—Certain black rocks, having a high specific gravity, and made up almost entirely of hornblende or colourless augite, or both, are found in places in this belt. They contain no olivine or rhombic pyroxene and very little feldspar, and agree, therefore, with Turner's definition of perknite (No. 50, p. 507).

Hornblende-pyroxene rock, Kelly's copper mine, near Walhalla.—This rock occurs as an intrusive pipe in a small gully on the eastern bank of the eastern branch of Stringer's Creek, near Maidentown. At the surface exfoliated boulders of the rock, stained with malachite and azurite, are common. Small quartz-veins, containing threads of yellowish-white asbestos of no economic importance, intersect the rock in places.

Specimen No. 275 is black in colour and coarse-grained. It appears to consist chiefly of black lustrous crystals of hornblende and pale green augite. A thin section of the rock, examined microscopically, is composed almost entirely of colourless monoclinic pyroxene and brown hornblende in approximately equal amounts, and their alteration-products chlorite, talc, and serpentine. A few flakes of chloritized biotite, a crystal or two of highly-sericitized feldspar, and a little ilmenite, magnetite, and apatite complete the rest of the section. Olivine is absent. The hornblende occurs in fairly large euhedral plates, and includes numerous rounded grains of augite, giving a fine example of micropœcilitic structure. Some green hornblende (actinolite) is also present. The normal mode of occurrence of the augite is in relatively small prisms and rounded grains. It gives extinction angles up to 50°, and is often simply twinned.

An analysis made of this rock by the writer gave the following result. Appended for comparison is an analysis of a similar rock described by E. O. Thiele from near Mount Wellington (No. 48, p. 257).

	1	2
	%	%
SiO_2	47.24	51.87
Al_2O_3	6.63	5.28
Fe_2O_3	1.53	2.29
FeO	8.05	7.37
MgO	18.69	22.52
CaO	12.92	8.71
K_2O	0.24	0.31
Na_2O	0.55	0.47
H_2O+	2.69	0.97
H_2O-	0.74	0.17
P_2O_5	n.d.	tr.
MnO	0.22	0.10
TiO_2	0.65	tr.
CO_2	abs.	—
Cr_2O_3	0.19	0.21
$(NiCo)O$	0.07	0.21
S	0.09	—
Cu	—	0.06
Totals	100.50	100.54

1.—Hornblende-pyroxene rock (perknite), Kelly's copper mine, near Walhalla; analyst, N. R. Junner

2.—Rock from near Monument Gap, Mount Wellington; analyst, G. Ampt.

The extremely low percentages of alkalies and alumina in the Walhalla rock are in keeping with the extreme scarcity of feldspar in it. The relatively high percentages of MgO and CaO show that the augite and hornblende are rich in these bases. The augite is apparently malacolite, a variety rich in CaO and MgO and poor in Al_2O_3.

Specimen No. 178, hornblende-pyroxene rock, about one mile east of Toombon.—This rock occurs as a lenticular pipe-like intrusion, having a length of about 900 ft. and a maximum width of about 300 ft. It appears to vary in composition from a diorite or gabbro-porphyrite to a hornblende-pyroxene rock, with very little feldspar and quartz. It is locally impregnated with chalcopyrite and pyrite, and stains of malachite and azurite are not uncommon at the surface. In thin section large hypidiomorphic phenocrysts of hornblende and colourless granular lime-rich pyroxene constitute the greater bulk of the rock. A little interstitial albite, quartz and micropegmatite, some accessory apatite and ilmenite, and the secondary minerals chlorite, carbonates, leucoxene, and pyrites complete the section. The hornblende is variously coloured. It is typically brown in the large anhedral plates, and marginally green or colourless. The brown hornblende is often surrounded by a zone of deep sea-green colour, which passes outwards into colourless jagged fibres of tremolite (*vide* microphotograph, pl. III., fig. 7). Occasional hornblende phenocrysts are anomalous, in that they show the form (100) and the absence of the usual form (010) after anthophyllite. Fine micropœcilitic inclusions of augite and ilmenite, and an occasional one of plagioclase, occur in the hornblende. Augite occurs in colourless grains, which are sometimes idiomorphic and simply twinned. The little feldspar that is present appears to be entirely acid plagioclase (albite), exhibiting both albite and pericline twinning. Quartz is uncommon, and appears to be mainly secondary. Chlorite is fairly abundant; it replaces some of the hornblende and augite. Minute grains and veinlets of chalcopyrite and pyrite occur, veining and encrusting the hornblende, augite, and plagioclase of the original rock. They are intimately associated with carbonates and chlorite, and are apparently of the same period of generation.

New Loch Fyne, copper and platinum-bearing dyke.—This rock occurs on the west side of the normal New Loch Fyne dyke. Its characters can best be studied in a crosscut from the main No. 5 adit level. It is here separated from the normal dyke by a narrow band of indurated and metasomatically altered (sericitized and carbonated) sandstone. In hand specimen it is a dense black rock in which flakes of biotite and occasional hornblende crystals are recognizable. Disseminated grains of chalcopyrite, pyrite, and pyrrhotite are common in certain portions of the intrusion, and assays of these mineralized parts have given up to 1.1 % copper and 1 dwt. of platinum. Numerous veins of ankeritic carbonate traverse the rock, but quartz-veins are extremely rare in it. All thin sections examined under the microscope show considerable metasomatic alteration. The original rock appears to have been composed of numerous large irregular-shaped phenocrysts of brown hornblende containing abundant rounded pœcilitic inclusions of biotite, augite, ilmenite, and, less rarely, feldspar, large twisted flakes of biotite, some colourless augite, and a little interstitial feldspar and accessory apatite and iron oxides. Quartz is absent. Veinlets of chlorite and carbonates replace the hornblende along cleavage planes, and black oxides of iron have separated out. Interlaminated lenticles of carbonate occur along the cleavage planes of the biotite, and some chlorite also replaces it in places. Pleochroic haloes are well marked in the chlorite which replaces biotite. Rutile webs are common in certain sections of bleached biotite. One identifiable plagioclase phenocryst in the section is largely replaced by sericite and carbonates, and another one is intersected by numerous more or less parallel veinlets of chlorite associated with a little carbonate (*vide* microphotograph, plate IV., fig. 12). Extremely compact aggregates of carbonates and sericite replace the bulk of the minerals of the original rock.

C.—METASOMATICALLY-ALTERED ROCKS.

(1) *Vein-Alteration.*—The petrological changes brought about by the regional magmatic and propylitic types of alteration have been briefly described in dealing with the diorite porphyrite from the Morning Star dyke (*vide supra*, p. 158), and will be discussed in greater detail in the sequel.

The visible effects of the hydrothermal alteration of the dykes by the vein-solutions are a bleaching of the wall rock, a reduction in the grain of the rocks, and the development in them of pyrite and arsenopyrite. Microscopically, it is seen that practically the whole of the original femic minerals have disappeared, and that much of the feldspar and some of the quartz have been replaced. Carbonates and sericite are extensively developed, and pyrite and arsenopyrite usually accompany them. Sometimes albite and quartz are formed by this alteration.

Specimen No. 78, Morning Star dyke, adjoining Age of Progress reef, Hope adit level; analysed specimen.—The hornblende is replaced in part by a flocculent whitish material resembling kaolin and partly by carbonates. Veinlets of carbonate and sericite traverse this material. Flakes of white mica, with interlaminated carbonates and inclusions of needles of rutile, are secondary after original biotite. The feldspar is largely sericitized and carbonated, and leucoxene replaces the ilmenite, and is in turn replaced by pyrite. Clear quartz and the accessories apatite and zircon and a little micropegmatite remain unaltered. Dusty carbonates and foils of sericite have been extensively developed.

New Loch Fyne dyke, adjoining quartz reef, No. 1 level below No. 5 adit level; analysis specimen.—This is a yellowish-green, fine-grained rock, containing numerous crystals of pyrite disseminated through it. No hornblende or chlorite remains, but a little quartz and micropegmatite have survived the metasomatic alteration. Clear feldspar, chiefly albite, with a little orthoclase, is fairly common in the section. It has probably developed from the original feldspar as a result of the vein-alteration. Leucoxene replaces ilmenite, and is in turn partially replaced by pyrite. Dusty and granular carbonates and aggregates of sericite replace the whole of the femic minerals and much of the feldspar.

No. 18, "Kindly country rock," within 1 ft. from quartz floor, 850-ft. level, A1 mine; analysis specimen.—A rather handsome rock, showing abundant plates of a colourless to light brown mica in hand specimen. No other mineral is recognizable. Under the microscope splendid pseudomorphs of carbonate, with a little sericite after idiomorphic hornblende, are visible. Foils of white mica, with interlaminated carbonates and lenticles of quartz along its cleavage planes, and including the usual "sagenitic webs" of rutile needles, are common. Veinlets of carbonates and sericite intersect the mica. Particularly interesting is the occurrence of numerous clear crystals of albite in the section, in one case showing Carlsbad and albite twinning and giving symmetrical extinction angles of 18° with refractive index less than that of quartz. The albite, although mostly unaltered, is partially secondarily carbonated, indicating that carbonation, in part at least, was later than formation of albite. A little micropegmatite remains in places. Pyrites is not common. Carbonates and sericite are very abundant. An analysis of this rock is given in Part II., p. 188.

No. 7, A1 mine, narrow dyke, close to quartz floor, No. 9 intermediate level; analysis specimen.—In hand specimen, under the microscope, the original rock is seen to have been more acidic than usual. It is fine and very even-grained, and consists for the most part of granular quartz, occasionally idiomorphic, stumpy-shaped prisms and laths of feldspar whose original characters are entirely masked by extensive sericitization, a little iron-magnesian mineral now departed, and fairly abundant needles and prisms of ilmenite. The rock appears to have been a fine-grained aplite dyke. The quartz has been greatly invaded and replaced by sericite and carbonates. Rutile and a little pyrite replace the ilmenite. Carbonates and sericite have been very freely developed at the expense of the minerals of the original rock.

J41, Luck's All dyke, near a quartz reef, lower adit level.—No hornblende or chlorite remains in this section. They are totally replaced by carbonates. Practically all sections of the feldspar, which was andesine with some acid labradorite and a little orthoclase, show signs of alteration, but in general the alteration was not intense, and the specific characters of the feldspar are readily determinable. Its alteration-products are sericite in blades and aggregates of flakes, with some dusty carbonates and a little zoisite. The bulk of the quartz is idiomorphic and little altered. Grains of leucoxene are scattered through the section. Sericite and carbonates in about equal amounts are the main alteration-products of the rock.

No. 37, Little Comet dyke, Wood's Point, adjoining quartz-vein, 220 ft. from surface.—This is a light grey-coloured rock containing abundant crystals of iron and arsenical pyrites distributed through it. It is intersected by a small quartz-vein lined with ankerite. No hornblende or chlorite remains. The idiomorphic outlines are preserved in a doubtful white cloudy material and in part in carbonates. The feldspar, which was albite, has been greatly sericitized. A little quartz, apatite, and sphene remain unaltered. Aggregates of sericite, dusty carbonates, and idiomorphic pyrite and arsenopyrite are common metasomatic minerals.

Contact of quartz-vein and dyke, Evening Star mine, Wood's Point.—This rock resembles the one last described. Albite appears to have been developed in considerable quantity at the expense of the original feldspars, and has in its turn suffered considerable sericitization and carbonation. No femic mineral remains. Quartz replaces some of the carbonate in part of the section, and euhedral pyrite and arsenopyrite are common.

Dyke near quartz-vein, Kelly's Hill mine, Matlock.—This is a greenish-grey rock characterized by the presence of abundant prismatic crystals of silvery mica in hand specimen. Viewed microscopically, the most prominent feature of this rock is the abundant foils and wisps of white mica. They are densely charged with rutile needles, and, normally, are extensively carbonated and occasionally partially replaced by chlorite. No original iron-magnesian mineral remains, although there is a moderate amount of granular and dusty chlorite distributed through the section. Feldspar has entirely disappeared, but its idiomorphic outlines can often be recognized preserved in aggregates of sericite and carbonates. A few relatively-large crystals of leucoxene, showing the characteristic ilmenite parting, are present in the section. Pyrite replaces much of the leucoxene. With the exception of a little apatite, granular and vein-quartz and abundant sericite and carbonates are the only other minerals in the rock, and these constitute by far the greater bulk of it.

Tubal Cain dyke, adjoining a quartz-vein, lower tunnel, Coronation mine, Walhalla.—The original rock was composed of porphyritic phenocrysts of augite and prisms of feldspar in a felted (andesitic) ground-mass, consisting of microlitic laths of feldspar, granules of augite, and abundant dusty grains of ilmenite or magnetite. As a result of the hydrothermal vein-alteration, the augite phenocrysts have been converted into a yellowish, cloudy, nondescript material, and numerous veinlets of carbonate intersect them. Densely packed aggregates of sericite replace all the feldspar, and the ilmenite grains have given place to leucoxene. Little or no quartz occurs in the section, and chlorite appears to be absent.

No. 278, Cohen's dyke, 3075 ft. level, Long Tunnel mine, Walhalla.—A greenish-yellow aphanitic rock traversed by veinlets of quartz. It is composed almost wholly of dense aggregates of flakes of sericite and dusty carbonates, with a little quartz and disseminated pyrite. Several veinlets of quartz and carbonate intersect the rock. Prismatic microlites of what appear to have been hornblende, and which are now chiefly sericite, are common. The sericite flakes have decided parallel arrangement, which imparts a fissility to the rock. The vein-quartz exhibits well-marked comb structure.

Quartz-vein in Cohen's dyke, 2925-ft. level, Long Tunnel mine, Walhalla.—This rock is very similar to the one last described, but pyrite and arsenopyrite are more abundant, particularly close to the vein. Some of the pyrite crystals are fringed with secondary quartz and one pyrite cube replaces vein-quartz. The bulk of the arsenopyrite is in double wedge-shaped crystals.

Dyke, Brohan's reef, "Pinnacles," near Aberfeldy.—This is a yellowish-green aphanitic rock traversed by veinlets of quartz. Small crystals of pyrite are disseminated through it. The original rock consisted of numerous panidiomorphic phenocrysts of feldspar and occasional smaller ones of quartz and biotite in a cryptocrystalline ground-mass. Dense felted aggregates of sericite now replace the feldspar phenocrysts in entirety. White mica replaces the biotite, and sphene or rutile has separated out. Quartz remains little altered. Grains of pyrite and arsenopyrite, the latter occasionally in form of cruciform twins, have been developed in the rock near the veins. Carbonates are absent.

Other dykes examined which have suffered similar carbonation, sericitization, and pyritization in the vicinity of quartz-veins are the Wallaby (near Gaffney's Creek), Georgia, Unknown, Waverly, and the Rose of Denmark.

(2) *Metasomatic Alteration of the Copper-Bearing Dykes.*—Low-grade copper ores—chalcopyrite, cupriferous pyrite, tetrahedrite, and nickeliferous pyrrhotite—occur as impregnations and small veins in certain basic and ultrabasic rocks of this belt—*e.g.*, Thomson River, diorite porphyrite and hornblendite; Toombon

and Kelly's copper mine, hornblende, pyroxene rocks; basic New Loch Fyne dyke, Aberfeldy peridotite, &c. In addition to copper, these ores invariably carry small quantities of platinum, silver, and gold.

The following table shows the result of some assays made of these dykes for the above-mentioned metals by the Mines Department of Victoria:—

Locality	Ore.	Platinum.	Gold.	Silver	Copper
		dwt. gr.	dwt. gr.	dwt. gr.	%
Thomson River Copper mine	Bore cores in dyke	av. 5 0	av. 1 0	av. 8 0	av. 3
New Loch Fyne, Matlock ..	Mineralized dyke ..	av. 1 14	av. 1 19	av. 6 17	av. 2.3
Kelly's Copper mine	Mineralized dyke ..	av. 1 0	av. 0 7	av. 2 3	0.31
Do.	Main dyke mass ..	0 3	trace	2 0	trace
Shamrock, Wood's Point	Mineralized dyke ..	0 13	0 3	1 2	1.01
Toombon Dyke	do.	0 4	0 4	1 3	(?)

The sulphides are invariably of later generation than the primary minerals of the original rock. They corrode, penetrate, and encrust the hornblende and biotite in the New Loch Fyne dyke, and replace and encrust the hornblende and feldspar in the Thomson River and Toombon dykes. They appear to be essentially contemporaneous with the chlorite, carbonates, and quartz that are intimately associated with them. Sericite is rare, and, when present, is seemingly of later generation. The sulphides occur normally as impregnations in the dykes, and very rarely as veins, which suggest that they were formed before the igneous rocks had cooled sufficiently to fracture and crack. Their period of formation is believed to belong to the propylitic stage of regional alteration.

The following thin sections of these cupriferous dykes illustrate the type of metasomatic alteration undergone by them and also the paragenetic relations of the sulphide minerals:—

No. 212, ore-bearing dyke, close to west wall, lower tunnel, Thomson River copper mine.—The original rock appears to have been intermediate between a diorite porphyrite and hornblendite. No hornblende remains, although its original idiomorphic outlines are recognizable in the form of pseudomorphs of carbonates and a nondescript yellowish flocculent material. In the alteration of the hornblende, magnetite or ilmenite dust separated out as a black border to the crystals, and was later replaced by chalcopyrite. Isolated relics of highly sericitized and carbonated feldspar and a little quartz and apatite are also recognizable. Dusty and idiomorphic grains of ankeritic carbonate are ubiquitous. The sulphide mineral, which appears to be entirely chalcopyrite, occurs in granular and dust-like form scattered through the section. In every case it is intimately associated with ankerite. In places the sulphide is moulded on and replaces the latter mineral, but in general they are essentially contemporaneous.

In specimen No. 220, from the same mine, the chalcopyrite occurs in granular form associated with carbonate and chlorite and some quartz. It encrusts hornblende and feldspar, and replaces the former mineral and micropegmatite in places.

No. 215, copper-bearing dyke, lower adit level, Thomson River copper mine.—In this rock most of the original minerals have disappeared, and often no trace of their former presence remains. Skeletons of one-time hornblende phenocrysts occur in the form of a white flocculent material greatly veined by carbonates, which latter constitute at least 50 % of the rock. Some chlorite and a little sericite are also present. Chalcopyrite is disseminated through the rock in intimate association with carbonates.

No. 292, ore containing pyrrhotite, stopes above upper adit level, Thomson River copper mine.—Massive pyrrhotite, with a little chalcopyrite, occupy the bulk of the section. The formation of the sulphides was preceded by the development of much chlorite and some carbonate. The pyrrhotite is veined by a copper-coloured mineral which gives reactions in the hand specimens for nickel, iron, and sulphur. Arsenic is absent, and the mineral is therefore apparently pentlandite. It is probably the source of the nickel obtained in the copper matte by the last company who worked this ore.

Another specimen (No. J61) from this mine is highly chloritized, but carbonates are not abundant. Well-developed laths of sericite cut the sulphides which occur in granular and dusty form.

Copper-bearing hornblende-pyroxene rock, 1 mile east of Toombon.—Green hornblende, secondary after the brown variety, and colourless granular augite make up the bulk of this rock. A little interstitial quartz and feldspar and some micropegmatite are also present. The hornblende in the vicinity of the sulphides has been corroded and partially replaced by chlorite, carbonates, and serpentine. Massive carbonates accompany the sulphides, which are mainly pyrrhotite, with a little chalcopyrite and pyrite fringing it. One or two laths of sericite penetrate the pyrrhotite.

No. J22, altered basic, New Loch Fyne dyke, No. 5 adit level.—This rock has suffered considerable metasomatic alteration. The bulk of the hornblende has been replaced by chlorite and a little carbonate. The alteration proceeds along cleavage planes and cracks, resulting in a mesh-like structure resembling that of serpentine after olivine. Apart from bleaching and partial conversion to chlorite, the biotite has suffered no great alteration. Occasional relics of feldspar crystals can be recognized, now veined and replaced by pennine and a little sericite. Some apatite and ilmenite remain little altered. Dense aggregates of carbonates and pennine are very abundant throughout the section. Some secondary sericite, quartz, and large irregular-shaped grains of chalcopyrite are also present. The chalcopyrite is associated intimately with carbonates, and in one place with quartz. Interaction has apparently taken place between biotite and chalcopyrite, resulting in rounding of the latter mineral and the embayment by corrosion of the biotite.

No. J16, carbonate vein carrying tetrahedrite and chalcopyrite in basic New Loch Fyne dyke, No. 5 adit level.—None of the minerals of the original rock, with the exception of a little apatite, remain. Pseudomorphs of chlorite (pennine), with a little carbonate and abundant grains and needles of leucoxene or sphene, occur, replacing hornblende. The characteristic sagenitic webs of rutile and the lath-shaped sections prove the presence of original biotite. It is now replaced by pennine and some carbonate. More than 90 % of the section is composed of carbonates and chlorite. The former predominates over the latter. A little secondary quartz has formed in places. The vein consists mainly of carbonates with a little vein-quartz and some tetrahedrite and chalcopyrite. Carbonates have replaced part of the tetrahedrite.

PART II.—METASOMATISM AND THE GENESIS OF THE GOLD.

1.—Metasomatic Alteration of the Dyke Rocks Associated with Auriferous Reefs.

As previously mentioned, three main types of metasomatic alteration are recognizable in the auriferous dyke rocks—

(A) A regional alteration during the final consolidation of the rocks by gases and mineralizers released from the cooling magma. This type of alteration may be sub-divided into—
   (a) Late magmatic stage.
   (b) Propylitization.

(B) An intense post-magmatic hydrothermal alteration of the dykes adjoining the vein-walls.

(C) Surface decomposition and oxidation by present-day vadose waters.

A.—REGIONAL ALTERATION.

(*a*) *Late Magmatic Stage.*—As a first stage in the regional alteration of the dyke expansions, the ground-mass has been partially re-crystallized in the form of a micropegmatitic intergrowth of quartz and feldspar. Some albite has been developed at the expense of the original feldspars, and secondary quartz is introduced into the rock. The phenocrysts are sometimes in optical continuity with the feldspar of the micropegmatite, as is the case in section No. 81, Evening Star dyke, Wood's Point; and in the Morning Star dyke quartz phenocrysts similarly merge into the quartz of the intergrowth. The bleaching of the hornblende and biotite and the actinolitic and tremolitic outgrowths to the former mineral are also referable to this alteration. In the narrow dykes quartz and albite are sometimes developed as a result of this alteration, but micropegmatite is usually lacking, probably due to their rapid cooling.

(*b*) *Propylitization.*—As a slightly later phase of the same alteration, we get developed the characteristic minerals of propylitization—namely, abundant chlorite after the femic minerals, and sometimes after feldspar; subordinate massive cleaved carbonate, distinct from the dusty type formed by the hydrothermal vein-alteration, inasmuch as it fills interstices between the rock-minerals rather than replaces them*; leucoxene after ilmenite and pyrite and pyrrhotite in turn replace the leucoxene. In addition, epidote and zoisite are often developed, but sericite is unusual. Chlorite variety pennine is the characteristic mineral of this type of alteration. The hornblende, biotite and augite of these rocks are all titaniferous. When hornblende or augite is replaced by chlorite, abundant grains of sphene and occasional needles of rutile separate out from them.

Excellent "sagenitic" webs of rutile are the rule in bleached and chloritized biotite. When the latter mineral is bleached and not chloritized black iron oxides usually separate out from it. The feldspars are occasionally chloritized, and epidote and zoisite replace them in certain cases, but sericite is less frequently developed. Quartz and apatite in general remain unaltered.

Chemical Changes.—In the late magmatic stage silica, alumina, and soda are introduced.

In the propylitic *facies* water, carbon dioxide, and sulphur are added, and occasionally some soda and potash. On the whole, there is no great change in the chemical composition of the rocks affected by this regional alteration.

It is claimed that the regional alteration undergone by these rocks is independent of the vein-solutions, and that the effects of the latter are superimposed upon those of the former. Concisely, the evidence for this conclusion is as follows:—

1. The minerals developed by the regional alteration are just as abundant 3 ft. away from the quartz reefs as they are 20 ft. away from them.
2. There is no mineralogical or chemical transition between the regionally and vein-altered rocks.
3. In one slide of the Morning Star dyke micropegmatite, albite, quartz, and chlorite are penetrated by a veinlet of quartz and carbonates.
4. The micropegmatite, quartz, and carbonates, and sometimes chlorite, fill interstices between the hornblende and feldspar of the original rocks and rarely replace

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* Granular carbonates occasionally replace the femic minerals in part.

these minerals, and in one or two sections there is a suggestion of an intergrowth of quartz and carbonates.

5. Apparently the rocks were not fractured when the regional alteration took place, for the minerals developed as a result of it are uniformly distributed through the dykes, and do not occur in or directly associated with veins. Chlorite, the characteristic mineral of the propylitic *facies* of alteration, practically never occurs in the quartz reefs, and is clearly seen to be replaced by carbonates and white mica in the wall rocks of the veins.

The almost invariable association of propylitization with the dyke rocks strongly suggests a magmatic origin for the gases or solutions causing the alteration. That the magma was a hydrous one is clearly proved by the abundant hornblende, biotite, and apatite—minerals which all require the presence of water for their formation (No. 5).

Hence it is believed that the gases and mineralizers responsible for the above-mentioned alteration had their origin in the cooling magma, and that their escape was made possible by the relief of pressure during intrusion.

Certain acidic dykes—quartz feldspar porphyries—described above (*vide* Part I., p. 152), exhibit a different type of alteration. Felted aggregates of sericite replace the porphyritic feldspar crystals, the biotite is bleached, and the ground-mass has been sericitized and partially silicified, and pyrites has been developed in small quantities. Carbonates are rare or absent, likewise chlorite, probably because of the paucity of the ferromagnesian minerals in the rock rather than the chemical nature of the mineralizers.

The ultimate product of this type of alteration is a rock composed of quartz, sericite, and pyrite, of the Diamond Creek dyke type (No. 27 p. 339). The extensive sericitization suggests a lower temperature alteration than the propylitization.

B.—HYDROTHERMAL ALTERATION ADJOINING THE VEIN-WALLS.

Adjoining the veins, for varying distances usually less than 1 ft., the dyke rocks have been bleached and rendered much finer-grained. Scattered crystals of pyrite and arsenopyrite normally are the only minerals recognizable in hand specimens of these altered rocks. The sulphides are most abundant near the vein-walls, and decrease in amount outwards from them.

(*a*) *Chemical Changes.*—The following analyses show clearly the nature and the trend of the alteration :—

	1	2	3	4	5	6	7	8
SiO_2 ..	49.65	39.92	48.47	44.45	48.06	42.73	56.91	7.42
Al_2O_3 ..	16.73	14.81	17.50	16.17	19.86	10.86	13.31	—
Fe_2O_3 ..	0.31	0.61	0.61	1.95	0.54	0.60	0.08	—
FeO	8.99	5.81	8.55	6.62	7.52	6.46	5.33	5.31
MgO ..	5.88	6.80	4.51	3.70	3.13	10.14	3.66	3.47
CaO ..	7.87	8.28	8.41	4.98	6.86	6.16	3.38	3.35
K_2O ..	0.80	3.51	1.23	2.76	0.99	1.80	3.76*	—
Na_2O ..	3.10	1.41	2.73	2.57	3.96	1.84	—	—
H_2O+ ..	2.50	1.03	3.10	1.68	2.21	0.81	1.19	—
H_2O- ..	0.14	0.23	0.07	0.31	0.30	0.28	0.13	—
CO_2	1.08	16.38	0.90	11.23	3.33	16.05	9.75	—
TiO_2 ..	2.81	1.26	2.45	2.10	1.82	1.22	1.40	—
MnO ..	0.14	0.09	tr.	0.15	0.12	n.d.	0.23	0.22
P_2O_5 ..	0.04	—	0.32	0.70	0.10	n.d.	abs.	—
Cr_2O_3 ..	—	—	—	—	0.03	—	—	—
NiO. CoO ..	tr.	tr.	nil	nil	tr.	—	—	—
BaO ..	—	—	—	—	0.05	—	—	—
SO_3 ..	—	—	nil	tr.	—	—	—	—
Cl ..	—	—	tr.	tr.	—	—	—	—
FeS_2 ..	n.d.	st. tr.	0.81	0.93	0.92	0.54	0.85	—
Totals ..	100.04	100.14	99.66	100.30	99.80	99.49	99.98	—

1.—Propylitized diorite porphyrite, Morning Star dyke, 10 ft. from Cherry's reef, Hope adit level; analyst, N. R. Junner.

2.—Vein-altered diorite porphyrite, Morning Star dyke, with 1 ft. of Cherry's reef, Hope adit level; analyst, N. R. Junner.

3.—Propylitized diorite porphyrite, New Loch Fyne mine, 5 ft. away from quartz "floor," No. 1 level below No. 5 adit level: analyst, F. Moss.

4.—Vein-altered diorite porphyrite, New Loch Fyne dyke, from within 1 ft. of same "floor" as in No. 3: analyst, J. C. Watson.

5.—Propylitized hornblende mica lamprophyre, A 1 mine; 10 ft. from quartz "floor," 850-ft. level; analyst, N. R. Junner.

6.—Vein-altered hornblende mica lamprophyre, A 1 mine, "kindly country-rock" of the miners, adjoining quartz floor, 850-ft. level; analyst, N. R. Junner.

7.—Vein-altered A 1 dyke, close to quartz "floor," No 9 intermediate level, A 1 mine; analyst, N. R. Junner.

8.—Extract from No. 7 above by dilute HCl at boiling temperature 7.42 % = total SiO_2, Fe_2O_3, Al_2O_3, &c., extracted. Analyst, N. R. Junner

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* Nearly all K_2O.

In all cases it is seen that SiO_2, H_2O, and TiO_2 have been considerably leached. also part of the FeO and Al_2O_3. and in two cases there is a marked reduction in Na_2O. The large reduction in the H_2O percentage is explained by the replacement of chlorite by carbonates and sericite. Potash has been increased considerably owing to the replacement of the soda-lime feldspars by sericite. In the Morning Star and A 1 rocks the magnesia percentage has been increased. In these same rocks the percentage of lime remains fairly constant, but in the New Loch Fyne it is considerably reduced.

The large increase in carbon dioxide is a result of the fixing of the bases CaO, MgO, MnO, and part of the FeO as ankerite. Comparison of analyses 7 and 8 show that practically the whole of these bases are in the form of carbonates. Furthermore, the amount of CO_2 required to fix the whole of the CaO, MgO. FeO. and MnO in analysis 7 is 9.82 %, which very closely approaches the amount determined by analysis—*i.e.*, 9.75 %.

If we consider the whole of this carbonate as being of uniform composition, then it has the approximate formula—

$$4\ CaO,\ 5\ (FeMn)O,\ 6\ MgO,\ 15\ CO_2.$$

In analysis 2 the theoretical percentage of CO_2 required to satisfy the whole of the above-mentioned bases is 17.89, while the amount determined by analysis is 16.38 %, showing that the bulk of the FeO, MgO, CaO, and MnO have been used up to form carbonates. In this rock some leucoxene and plagioclase feldspar containing CaO remain, explaining the excess of the bases.

In the New Loch Fyne case the amount of CO_2 necessary to fix the same bases as carbonates is 12.12 %. However, some apatite and leucoxene remain in the rock, explaining the excess of 0.89 % CO_2. The reversal of the alkalies is not so complete in analyses 4 and 6 as in the Morning Star example. The reason is that some fresh albite has been developed in the New Loch Fyne and A 1 dykes as a result of the vein-alteration.

Analysis 7 appears anomalous in some respects. Microscopical examination of a thin slice of the rock, however, shows that it is the vein-altered *facies* of a rock much more acid than the normal A 1 hornblende mica lamprophyre. It probably represents an altered vein in the normal dyke.

(*b*) *Mineral Changes.*—As a result of the hydrothermal vein-alteration, the femic minerals hornblende and chlorite have been the first to break down. Near the veins they are completely replaced. Where the hornblende has been previously chloritized it gives rise to cabonates with or without sericite, and a little quartz. In many cases, however, the hornblende has not been chloritized prior to the attack by the vein-solutions. In such cases it is, in part, converted to a white or cream-coloured flocculent material, probably a hydrous aluminium silicate. In the process most of the FeO, MgO, and CaO have been leached and re-deposited in the form of ankerite, which almost invariably accompanies this (?) mineral. This description of the alteration of the hornblende applies equally well to augite, but the trend in biotite is usually in a different direction. In the regional alteration of this mineral it may either be replaced by chlorite, and possibly epidote, with the separation of rutile, or be bleached. As a result of the vein-alteration the chlorite and epidote are replaced by carbonates for the most part, and sometimes lenticles of quartz have formed along the cleavage planes. The bleached biotite, on the other hand, gives rise to white mica, with interlaminated carbonates and a little quartz.

Leucoxene and granular sphene replace the whole of the ilmenite, and they are, in turn, frequently replaced by idiomorphic pyrite and arsenopyrite, and sometimes by carbonates. Normally, the feldspars become highly sericitized, but often albite is developed as a result of the vein-alteration—*e.g.*, in the New Loch Fyne, A 1, Rose of Denmark, Evening Star, and Working Miners' dykes. In such cases it is also generally present in the adjoining quartz-veins. Furthermore, albite is often developed in the process of replacement of the dyke wall rock by the vein-quartz, as in the Morning Star, Rose of Denmark, and Working Miners' mines. Carbonates partially replace the feldspars in certain cases, and a little secondary quartz is sometimes formed at the same time.

The only stable minerals are quartz and apatite, and their stability is only relative, as they sometimes suffer attack and replacement. Of the secondary minerals, dusty carbonates and flakes of sericite are most abundant. Frequently they comprise more than 50 % of the altered rock. The intensity of carbonation appears to vary in a general way with the basicity of the rock. Carbonates are absent in certain vein-altered quartz porphyries from Brohan's reef, junction of Jordan and Thomson Rivers, &c., while in the altered ultra-basic rocks—*e.g.*. New Loch Fyne dyke—they sometimes constitute more than 50 % of the rock. Sericite, on the other hand, is extensively developed in the acidic types, and is not so abundant in the altered basic and ultra-basic rocks. Another peculiar feature is that pyrite is often more abundant in the sericitized rocks than in the highly carbonated ones.

The calculated approximate mineral compositions of some of these vein-altered rocks are given in the accompanying table ·—

—	1	2	3
	%		
Sericite*	29.75	23.40	40.00
Ankerite	35.82	25.54	22.20
Albite	11.92	21.72	—
Quartz	16.30	16.70	35.40
Anorthite	2.86	—	—
Rutile	—	1.79	1.40
Leucoxene ..	3.09	0.77	—
Apatite	—	1.54	—
Pyrite	—	0.93	0.85
Kaolin	—	4.50	—
Excess Al_2O_3 ..	—	1.14	—
Fe_2O_3	0.61	1.95	0.08
	100.35	99.98	99.93

1.—Vein-altered diorite porphyrite within Morning Star dyke, with 1 ft of Cherry's Reef, Hope adit level.

2.—Vein-altered diorite porphyrite, New Loch Fyne dyke, from within 1 ft. of quartz "floor," No. 1 level below No. 5 adit level.

3.—Vein-altered A 1 dyke close to quartz "floor," No. 9 intermediate level, A 1 mine.

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* Theoretical muscovite.

The following table sums up the progressive changes in the mineral composition of these rocks as a result of the magmatic, propylitic and vein-alteration undergone by them.

Magmatic Minerals.	Magmatic Alteration.	Propylitisation.	Vein-Alteration.
Hornblende	Actinolitic and tremolitic outgrowths and partially bleached	1. Hornblende	1. (?) Yellowish-white flocculent material and carbonates
		2. Chlorite with a little carbonate; separation of sphene	2. Carbonates and sericite and a little quartz
		3. Chlorite and magnetite, pyrite	3. Carbonates and pyrite
Augite	Augite	1. Augite	1. Carbonates and cream-coloured flocculent material
		2. Chlorite and serpentine	2. Carbonates and sericite
Biotite	Bleached in part	1. Bleached, rutile and magnetite separate	1. White mica, carbonates, quartz and rutile, pyrite after magnetite
		2. Chlorite and a little epidote, rutile and magnetite separating out	2. Carbonates and white mica and rutile wisps
Plagioclase	Albite in part	1. Albite	1. Albite, sericite and carbonates
		2. Chlorite and a little carbonate	2. Carbonates
		3. Sericite rare	3. Sericite
Orthoclase	Orthoclase	1. Little chlorite, sericite and carbonates	1. Sericite, carbonates and a a little quartz
		2. Epidote and zoisite	2. Carbonates
Ilmenite	Ilmenite	Leucoxene, pyrrhotite and pyrite	Sphene, carbonates and pyrite
Quartz (?)	Interstitial quartz formed	Quartz	Partial replacements by carbonates and sericite
	Interstitial micropegmatite quartz & albite	Interstitial carbonate	Very little micropegmatite remains

(c) *Summary of Effects of Alteration by the Vein-Solutions.*—The holocrystalline medium to coarse-grained melanocratic rocks of the propylitic *facies* are converted into yellowish-green aphanitic rocks impregnated with pyrite and arsenopyrite.

Chemically, CO_2 and K_2O have increased greatly and MgO slightly. Na_2O, SiO_2, and H_2O have been markedly reduced, and TiO_2, FeO, and Al_2O_3 partially leached.

The microscope shows that, with the exception of apatite and some of the quartz, all the minerals of the original rocks have succumbed to the intense chemical action of the alkaline carbonate vein-solutions and have been replaced, for the most part, by ankeritic and dolomitic carbonates and sericite, usually with some quartz, albite, pyrite, and sphene and rutile.

Chlorite (pennine), the characteristic mineral of the propylitized rocks, entirely disappears close to the vein walls, and apparently is unstable under the action of the vein-solutions. Sericite, which is rare in the propylitized rocks, is extremely abundant in the vein-altered ones. The carbonates of the propylitic *facies* are massive and cleaved, and fill interstices between the rock-minerals, while those of the vein-altered wall-rocks are dusty and granular, and occur replacing the same minerals. The progressive stages in the replacement of the minerals are extremely well illustrated in thin sections of these rocks. As usual, the femic minerals in the order hornblende, biotite, augite, are the first to disappear. Alteration starts along microscopic cracks and cleavage planes in these minerals, and rapidly spreads inwards. Fine pseudomorphs of carbonates and sericite after idiomorphic hornblende, augite, and biotite can often be recognized.

The effects of the regional, magmatic, and propylitic alterations are, in the main, constructive. Much of the micropegmatite, quartz, albite, carbonates, and pyrrhotite which are formed at this stage fill interstices in the rocks.

Destructive metasomatic replacement is largely confined to chloritization and the formation of leucoxene, with the development of a little carbonate, epidote, pyrite, and sericite. The hydrothermal alteration, on the other hand, as has been shown, is intensely destructive.

There seems every reason for believing that the attacking solutions in both cases were of similar composition—*i.e.*, rich alkaline carbonate solutions. What, then, is the cause of the difference in their effects? The results of Konigsberger's and Müller's experiments indicate a possible explanation (No. 30, p. 569). According to these workers, the attack of alkaline carbonate solutions on various rock-forming minerals appears to become considerable at those temperatures at which they become strongly hydrolyzed, and that free CO_2 diminishes the activity of the alkali. They showed that quartz, muscovite, and adularia were dissolved completely in a 20 % solution of Na_2CO_3 at 350° C., and that water containing both CO_2 and Na_2CO_3 had very little action on quartz, adularia, muscovite, sphene, biotite, &c., at 370° C.

It seems reasonable to expect that free CO_2 would be present at the higher temperatures of the regional magmatic and propylitic alterations, which would explain their minor destructive effects. The vein-solutions, on the other hand, probably contained little or no free CO_2, and their temperature was such that they were strongly hydrolyzed, resulting in the intense destructive metasomatic alteration of the wall-rock.

C.—NOTES ON CERTAIN MICAS OF METASOMATIC ORIGIN.

White micas, containing abundant inclusions of needles of rutile and often interlaminated carbonates, are common in the metasomatically-altered dyke rocks of this belt. It was at first thought that they were ordinary muscovite or sericite, but chemical and microscopical examination has proved without doubt that most of them are bleached and carbonated biotite.

Silvery flakes of mica were isolated from the Kelly's Hill dyke, near Matlock, and subjected to examination. Under the microscope basal sections showed some carbonates and abundant "sagenitic" webs of rutile. Some of the mica was treated with acid to remove the carbonates and then examined under convergent polarized light. A black cross, which hardly divided on rotation, was obtained with certain flakes, and in all cases the optical axial angle was small compared with flakes of muscovite of approximately equal thickness.

A chemical analysis of the impure mica, and also a partial analysis of the extract by dilute hydrochloric acid at the boiling temperature of water, gave the following results, viz.:—

	1 %	2 %
SiO_2	35.32	—
Al_2O_3	13.72	—
Fe_2O_3	0.55	—
FeO	6.99	5.45
MgO	7.65	3.96
CaO	9.53	9.33
K_2O	3.93	—
Na_2O	1.12	—
H_2O+	2.59	—
H_2O-	0.67	—
CO_2	14.95	—
TiO_2	3.72	—
MnO	—	—
P_2O_5	abs.	—
Total	100.74	

1.—Impure white mica in vein-altered dyke, Kelly's Hill mine, near Matlock Analyst, N. R. Junner.

2.—Extract from "1" with dilute HCl at boiling temperature. Analyst, N. R. Junner.

The ratio of silica to alumina, combined with the relatively high percentage of TiO_2, suggests at once that this mica belongs to the biotite class, and this belief is strongly supported by the above-mentioned optical examination of it.

A similar white mica separated from the vein-altered A 1 dyke (specimen No. 18, analysis No. 6—*vide supra*, p. 188) gave 2.8 % TiO_2 on analysis, confirming the presence of rutile, which is seen in sagenite webs under the microscope. Biotite has been noted in the propylitic *facies* of the A 1 dyke, and, without doubt, the white mica is the bleached form of this mineral.

Other metasomatic white micas of a similar kind occur in the altered Rose of Denmark, Alabama, Ten-Mile, New Loch Fyne, and Waterloo Gully dykes.

The presence or absence of included needles of rutile in these micas is a useful criterion in determining their original characters.

Hand specimens of certain highly carbonated basic rocks—*e.g.*, New Loch Fyne, Hunt's, and the A 1 dykes—often contain small patches and spots of an apple-green coloured mineral. Examined microscopically, this mineral is seen to occur in colourless or light green coloured wisps and laths. It is slightly pleochroic in some sections, and its polarization colours are high, approaching those of muscovite, which distinguishes it at once from chlorite, and suggests that it is either chrome or vanadium mica.

A partial analysis of a highly-carbonated green-coloured variety of the New Loch Fyne dyke, from No. 5 adit level, gave 0.29 % Cr_2O_3, and failed to detect any V_2O_3. A thin section of the rock examined under the microscope showed the presence of flakes of a light green pleochroic mica in addition to sericite, carbonates, rutile, and quartz. Consequently, there can be little room for doubting that the Cr_2O_3 is resident in the green mica. To discover whether or not the Cr_2O_3 had been introduced in the hydrothermal solutions, an analysis was made of the least-altered dyke from the same vicinity for Cr_2O_3. The result, 0.23 % Cr_2O_3, indicates that the chromium was originally present in the rock.

2.—ORIGIN OF THE VEIN CONDUITS IN DYKES.

A.—CONTRACTION, JOINTING, AND FAULTING.

Several views have been expressed as to the origin of the vein-channels in the dykes.

According to H. Thompson (No. 49, p. 246), "The flat veins of quartz in the diorite dykes do not penetrate to any great depth, and are really detached strings of quartz having no connection with one another."

Phillips (No. 39, p. 643) claimed "that the origin of the 'floors' was due to the filling of cracks near the surface by secondary solutions due to the breaking down of auriferous pyrites."

Mr. O. A. L. Whitelaw (No. 55, p. 13) regarded the quartz reefs as filling contraction-fissures in the dykes caused by the drying and cooling of the plastic dyke-mass.

W. Lindgren (No. 31, p. 134) has expressed a doubt that the last-named explanation is the correct one in the case of the reefs in the Morning Star dyke.

The writer's own study of the question has convinced him that two factors—contraction-jointing and orogenic movements—have led to the formation of the greater bulk of the vein-channels.

In the narrow dykes he is of the opinion that many of the veins fill contraction joints. The evidence for this view is as follows:—

(1) The quartz-veins in these dykes frequently occur in form of flat, apparently disconnected "ladder veins," which usually end abruptly at the dyke walls.

(2) Where the reefs continue out into the country-rock they soon fray out and disappear.

(3) Prismatic jointing is common in many of these dykes.

As previously mentioned, many, if not most, of the reefs in the dyke expansions occur in faults. However, prismatic jointing parallel to the main reefs is particularly well developed in certain of these dykes—*e.g.*, Morning Star, A 1, and New Loch Fyne. Infilling these joints in practically every instance are embryonic veins—threads of quartz and carbonate which are sometimes auriferous, and which rarely exceed one quarter of an inch in thickness. Similar joints, containing veinlets of quartz, occur in the strata in the immediate vicinity of the dykes in some cases. It is probable that the original jointing of these dyke expansions was determined by contraction, and that movement occurred along these planes prior to the introduction of the quartz.

On the other hand, numerous instances have been noted of reefs occupying strike-faults which are quite independent of contraction-jointing (*vide supra*, p. 145).

B.—REPLACEMENT.

A study of thin sections of many of the reefs occurring both within dyke rocks and within Silurian slates and sandstones indicates that they have been formed in part by the gradual metasomatic replacement by quartz of the wall-rock surrounding small cracks and fissures.

In reefs in the strata a laminated or brecciated character is the rule—*e.g.*, Cohen's Creek, Harbinger, Fulton's, Bismarck, Sailor Bill, Ten-Mile, and numerous others. Thin slices of these reefs examined microscopically show that the brecciated fragments of the wall rock have been partially replaced by quartz, albite, pyrite, and sericite. Some sections show the complete replacement of the included fragments by interlocking grains of quartz and dusty pyrite and the separation of black opaque rock residues. The laminations are composed chiefly of granulated quartz, pyritized films of the wall-rock, and finely-divided pyrite and arsenopyrite.

Many of the reefs within the dykes have been enlarged by the replacement of the dyke wall-rock, as will be seen from the following examples:—

Specimen No. J5, auriferous vein-quartz, 400-ft. level, Morning Star mine.—Included fragments of the dyke wall rock are present in this section. They are replaced for the most part by granular quartz and prisms and laths of clear albite. Sericite and pyrite and a little carbonate are also present. The boundaries of the inclusions merge gradually into coarsely crystalline vein-quartz. A further stage in the replacement is seen in places in the same slide. A mosaic of irregular-bounded interlocking grains of quartz associated with some yellow leucoxene and rutile, dusty rock residues, and a little finely-divided pyrite, are all that remain of the inclusions.

Specimen No. 11A, rich floor, No. 9 intermediate level, A 1 mine. —The greater bulk of the quartz in this portion of the reef is of replacement origin. Former brecciated fragments of the wall rock are now converted into aggregates of granular quartz and dusty pyrite. Much of the pyrite occurs in parallel lines or laminations associated with opaque rock residues and replacing the latter.

Specimen No. J7, stopes below No. 9 level, A 1 mine.—Two types of quartz are present in this section—

(1) Coarse vein-quartz, often idiomorphic, and exhibiting comb structure in places. Some bournonite is present in this quartz, but no gold.

(2) Finely-granular anhedral quartz admixed with abundant dusty and granular pyrite and a little leucoxene close to the vein-walls.

Specimen No. J7B, stopes below No. 9 level, A 1 mine.—Numerous skeletons of included slate fragments partially replaced by quartz, chlorite, carbonates, sericite, and dusty pyrite are present in this section. In nearly all cases the chlorite fringes the inclusions. The bulk of the quartz is of the ordinary vein-type.

No. J10, contact of vein-quartz with dyke, No. 6 level below main adit level, Rose of Denmark mine.—The sericitized and carbonated dyke wall rock has been extensively replaced by a granular quartz mosaic with some carbonate and sericite and pyrite. Traces of leucoxene, apatite, sericite, rutile, pyrite, and arsenopyrite remain from the original rock. The bulk of the sericite has been replaced by albite and quartz, and the dusty carbonates have given place to a more massive type. The vein consists of albite, carbonate, and quartz, and represents a further stage in the replacement.

This specimen has been subjected to considerable pressure, as is proved by the curved and fractured laths of albite and carbonate, and by the strain polarization and granulation of the quartz.

No. J15, contact of dyke, vein-quartz, and included slate fragments, main adit level, Working Miners' dyke, Kevington.—Skeletons of former dyke inclusions in the quartz-veins are present in form of mosaics of interlocking quartz grains with a little finely-divided pyrite. Pellucid albite has been developed round these inclusions. The slate fragments, in which detrital grains of blue tourmaline and colourless zircon are common, have been greatly sericitized and carbonated, and in places replaced by quartz, clear albite, and dusty pyrite. The latter mineral appears to be replacing residual rock dust for the most part.

As in the previous example, effects of pressure are evident in the twisting of the laths of albite, strain polarization in the quartz, and in the fracturing of the grains of pyrite and arsenopyrite. Carbonates fill the fractures in the sulphides.

No. J42, dark-coloured auriferous quartz, wall of No. 2 reef, stopes from No. 2 level below main adit level, New Loch Fyne mine.—By far the greater part of the quartz is replacing dyke material. The process of replacement has reached an advanced stage, although numerous sericitized and carbonated inclusions of the dyke wall-rock, partially replaced by quartz, can be recognized. Grains of pyrite and tetrahedrite (?) are scattered through these inclusions and also through the quartz, giving to it the dark colour seen in hand specimens. Some fresh albite is visible in places, and much of the quartz appears to be replacing this mineral, whose prismatic shape and cleavage it has retained. Relics of leucoxene and rutile are not uncommon in the rock. The gold occurs in minute grains deposited on pyrite and tetrahedrite (?), and in one place on carbonates and veining quartz in a partly replaced fragment of dyke. An irregular lamination, consisting of finely-divided pyrite and tetrahedrite associated with some ankerite, traverses the vein. Effects of pressure are noticeable in the strain polarization and granulation of the quartz.

Laminated quartz, stopes above No. 2 level below main adit level, New Loch Fyne mine.—Two distinct laminations are present in this section. One of them is composed chiefly of carbonates, and is traversed by a narrow veinlet of arsenopyrite, pyrite, and jamesonite (?). The other consists of granular arsenopyrite, pyrite, and jamesonite (?), which latter mineral occurs in silvery-grey, vertically striated prisms and needles, and in massive form, replacing pyrite in part. The laminations are not of replacement origin. They appear to be slip-planes or minute fractures in the quartz. The bulk of the latter mineral is of the ordinary fissure-filling type.

C.—FISSURE-FILLED VEINS.

On the other hand, there is abundant evidence that much of the quartz has been deposited from solution in open spaces. Comb structure—prisms of quartz, carbonates, and sometimes albite projecting from the vein-walls—is well developed in many reefs in dykes—*e.g.*, Little Comet, Hunt's, New Loch Fyne, Blue Jacket, A1, &c. In many cases—*e.g.*, Evening Star dyke, Wood's Point—prisms of quartz, pyramidally terminated, project inwards from each wall of the vein, leaving an open space between the crystals.

Drusy cavities or vugs, sometimes of large size, are common in many of the reefs in the dyke bulges—*e.g.*, Evening Star, New Loch Fyne, Eldorado, A 1, &c. Coarsely-crystallized quartz, dolomite, and calcite occur in these cavities. The loosely crystalline character of the quartz in certain reefs is also suggestive of fissure-filling.

Both replacement and fissure-filling may occur in the same reef within a few feet of one another.

For instance, the rich, narrow, laminated reef of replacement origin worked at present by the New Loch Fyne Company between No. 1 and No. 2 levels, below the main adit level, passes in places into a wide, poorly auriferous reef in which the laminated structure is absent. The quartz shows comb structure, and is in part crystalline and vuggy.

3.—THE ORIGIN OF THE GOLD.

The following views have been expressed at various times as to the origin of the gold in the reefs of this belt.

Mr. H. A. Thompson (No. 49, p. 218), dealing with the Wood's Point reefs, claimed that the mineral contents of the veins were derived from the rocks bounding them. He further states that

"Near the surface these dykes are much decomposed, and in this condition the quartz veins traversing them have yielded large quantities of gold ; but as the rock becomes hard and compact at a greater depth the gold in the veins decreases, indicating that this decomposition of the bounding rock and the consequent liberation of the contained gold was necessary to the aggregation of the latter in the quartz veins. The dyke may contain quite as large an amount of gold where the quartz veins are worthless as it does where they are rich, but it will require long ages to pass over them before the necessary changes are affected that would render the gold available."

According to Mr. R. A. F. Murray (No. 34, p. 70), the general appearance of the reefs in this district is greatly in favour of the theory that the quartz-veins and the contained metals and minerals were segregated from the surrounding rocks into cracks and fissures.

In his "Geology of Victoria" (No. 35, pp. 122 and 123), Mr. R. A. F. Murray quotes the late Dr. Howitt's view that the gold of our reefs came from the sea water of Silurian times, and was later collected together by hot solutions from granitic magmas.

Mr. Mennell (No. 33, p. 396), in his description of the Morning Star dyke, suggested that the gold came from minute quantities of gold present in the adjoining sediments and was re-deposited in the quartz-veins by the action of heated acid waters connected with the intrusion of the dyke.

Let us now examine these and other theories usually advanced to account for the origin of the gold, and see how far they conform to the facts.

1.—The gold was deposited with the Silurian sediments and was later collected and concentrated by hot ascending waters.

Dr. A. W. Howitt and Messrs. R. A. F. Murray, E. J. Dunn, and T. S. Hart have supported this theory. To test it, Dr. Don (No. 10, p. 568) analyzed the country-rock (slates and sandstones) from the deeper levels of the Long Tunnel mine, Walhalla, at various distances from the lode. His results showed that no gold exists in the sedimentary rocks away from the quartz-veins and dykes, and that a marked inverse ratio exists between the auriferous contents and the distance from the lode.

Furthermore, this theory receives no support from the mode of occurrence of the gold.

2.—The gold was originally present in the minerals—*e.g.*, hornblende, augite, and biotite—of the dykes.

In numerous localities in Australia and New Zealand auriferous quartz-veins occur in or directly associated with igneous rocks rich in hornblende—*e.g.*, Kalgoorlie (W.A.), Hauraki (New Zealand), Charters Towers and Mount Morgan (Queensland), Walhalla, Wood's Point, Dargo, Rheola (in Victoria); and, according to Mr. Pittman (No. 40, p. 62), "In every case in New South Wales where auriferous reefs are associated with granite the latter is hornblendic." Exotic occurrences of a similar nature are very common—*e.g.*, Transylvania, Comstock, Juneau (Alaska), &c.

Numerous writers have claimed that the gold in these deposits was originally present in the hornblende and other minerals of the igneous rocks.

G. F. Becker (No. 4, p. 224) has suggested that the repository of the silver and gold of the Comstock lode was the augite and other iron-magnesian minerals of the diabase country-rock.

Prof. F. W. Hutton (No. 26, p. 272), speaking of the Hauraki goldfield, says:—"There is no reasonable doubt that the gold came from out of the volcanic rocks, and was not brought into them from below."

B. von Inkey (No. 51) believed that the hornblende, augite, and possibly biotite were the source of the precious metals found in the Transylvanian andesites and dacites.

C. G. Gibson (No. 42, p. 29) suggests that at Kalgoorlie the gold was originally present in the iron-magnesian minerals of the greenstones, and on their alteration to chlorite the gold was released.

F. R. Feldtman (No. 14, p. 91), however, expresses a doubt that this explanation is the correct one.

H. A. Thompson (No. 49, p. 248) claimed that at Wood's Point the mineral contents of the veins were derived from the rocks bounding them.

To test this theory at Walhalla, Dr. Don (No. 10, p. 575) made comprehensive analyses of—

(1) Cohen's dyke, containing no sulphides, and not associated with an auriferous quartz reef.

(2) Cohen's dyke, associated with such reefs.

(3) Hornblende separated from Cohen's dyke and the Thomson River copper mine dyke.

His results indicate that when no quartz is associated with Cohen's dyke the rock contains little or no sulphides, and is non-auriferous; that where the dyke is associated with quartz, but the quartz is not auriferous, the dyke is likewise barren; that the percentage of sulphide in the dyke is greatly increased when it is associated with highly pyritiferous quartz, and that in this case the dyke sulphides are auriferous, though much less than those of the associated reefs; and that not a trace of gold is present in the hornblende (No. 10, p. 652).

Thanks to the courtesy of Mr. M. Copland, the following assays were made for the writer by Mr. H. R. Murphy, lecturer in assaying at the School of Mines, Ballarat, of propylitized and vein-altered rocks from the vicinity of Wood's Point and Gaffney's Creek:—

No. 24.—Propylitized mica hornblende lamprophyre, A 1 mine	No gold detected
No. 67.—Propylitized diorite porphyrite, 400-ft. level, Morning Star mine	No gold detected
No. 7.—Vein-altered dyke containing a little pyrites, No. 9 intermediate level, A 1 mine	No gold detected
No. 135,—Vein-altered dyke with very little pyrites, Hunt's mine	No gold detected
No. 46.—Vein-altered dyke containing a good deal of pyrites, Hope adit level, Morning Star mine	3.5 gr. of gold per ton

These results suggest that there is no gold inherent in the propylitized rocks away from the quartz-veins, and that gold is only present in the vein-altered types when pyrites is present.

The following field and petrological evidence supports Dr. Don's conclusions that the gold has not been derived from the hornblende or other minerals of the dyke rocks associated with the reefs:—

(1) The history of mining in this belt has shown that the most payable reefs occur in association with dyke rocks of intermediate to basic composition, and that quartz-veins associated with the more acid and more basic types have yielded little gold. If we accept as a premise that the dykes are consanguineous, then it would appear that the origin of the gold is a factor of the differentiation of the dykes.

(2) We should expect that the metasomatically altered rocks which were originally very rich in hornblende and other iron-magnesian minerals, such as the Aberfeldy peridotite, hornblendite from Thomson River copper mine, and Shamrock's dyke, Wood's Point, should be associated with rich gold values. The reverse is the case. These dykes contain copper, platinum, and silver in small quantities, but gold is usually lacking or present in very small amounts.

(3) The theory does not explain the occurrence of gold in the quartz-veins in the sedimentary rocks outside the dyke belt.

(4) The unaltered or slightly altered dyke rocks should be richer in gold than the highly metasomatically altered ones. This is not the case, as Dr. Don's results and Mr. Murphy's assays show.

3.—The gold came from magmatic sources. Practically all the available evidence is in support of this theory.

That the veins were formed from solutions passing through cracks and fissures in the dyke rocks is certain from the replacement of the wall-rock adjoining the veins and the comb structure exhibited by many reefs.

The nature of the minerals formed by the intense metasomatic alteration of the dyke wall rocks by the vein-solutions shows that the latter were considerably heated ascending solutions rich in alkaline carbonates, and containing also small quantities of iron, sulphur, arsenic, antimony, &c. That these solutions were the vehicles for the introduction of the gold is undoubted. Gold is known to be soluble in alkaline sulphides, and such were present in the vein-waters.

The constant association of the auriferous veins with dyke rocks of dioritic and gabbroidal composition is more than fortuitous, and admits of only one conclusion—namely, that they are of congeneric origin. The reefs occur within, intersecting and directly associated with the dykes, and nowhere do the latter cut the former.

The magma from which the dykes originated was a hydrous one, as is proved by the abundant hornblende, biotite, and apatite in these rocks. Furthermore, the regional magmatic and propylitic alterations were caused by silicious and alkaline carbonate waters of magmatic origin, and it seems reasonable that the alkaline carbonate vein-waters had a similar genesis.

4.—Paragenesis of the Vein-Minerals.

The opaque minerals present in the veins are pyrite, arsenopyrite, bournonite, tetrahedrite, sphalerite, galena, chalcopyrite, stibnite, jamesonite, and gold.

The gangue minerals consist of quartz, calcite, dolomite, ankerite, albite, and occasionally sericite, and in one case chrome-bearing mica.

The percentage of sulphides in the reefs averages about 1 %.

The gold is generally free, and in most cases it is fairly coarse. In many mines the gold is intimately admixed with bournonite. Thin sections of the ore from the A 1 mine show the relationship of these two minerals very well. In one specimen from the 850-ft. level the bulk of the gold is disseminated through the bournonite, and in places encrusts it. In other parts of the section veinlets of bournonite traverse the gold. Idiomorphic quartz crystals and some sphalerite are included in the bournonite. The sphalerite is coated and replaced by bournonite and chalcopyrite, and the latter mineral encrusts the bournonite.

Specimen No. J11, rich ore, No. 9 intermediate level, A 1 mine.—The gold is disseminated through the bournonite, and both minerals vein and replace sphalerite. Practically the whole of the gold is in direct association with the bournonite. Quartz and pyrite and sphalerite are included in this latter mineral, and some of it replaces finely-divided pyrite. That both the gold and the bournonite are essentially contemporaneous is undoubted.

In many mines the gold is more intimately associated with arsenopyrite. This is the case in the Morning Star and Rose of Denmark mines and in most of the narrow dykes—*e.g.*, Dempsey's, Star of Erin, Little Comet, Georgia, and Long Tunnel, &c.

In specimen No. J5, from the 400-ft. level, Morning Star mine, the gold occurs coating, veining, and replacing the arsenopyrite, and no gold is seen away from this mineral.

In another specimen from the No. 2 level below main adit level, Rose of Denmark mine, the gold occurs encrusting and veining the arsenopyrite, and both minerals are later than the quartz.

In specimen No. J8, No. 9 intermediate level, A 1 mine, the gold occurs intimately associated with arsenopyrite along an irregular lamination in the quartz ; portion of the gold veins and replaces the arsenopyrite.

In a thin section of auriferous quartz from the 220-ft. level, Little Comet mine, the gold in part encrusts arsenopyrite, and both minerals vein the ankerite and quartz.

Pyrite is a common vein-mineral. It is almost invariably auriferous, but examples of visible gold in direct association with it are unusual, except near the surface, where the gold has been released by the breakdown of the pyrite—*e.g.*, All Nations and Champion mines.

In specimen No. J2, 850-ft. level, A 1 mine, the bulk of the gold occurs encrusting finely-divided pyrite of replacement origin.

In specimen J42, dark-coloured auriferous quartz, No. 2 level below main adit level, New Loch Fyne mine, some of the gold is deposited on grains and strings of pyrite of replacement origin.

At least two generations of pyrite are recognizable in the quartz-veins—

(1) Dusty and granular pyrite, replacing with quartz brecciated fragments of the wall-rock. This type antedates all the other vein sulphides.

(2) Granular and euhedral pyrite, apparently introduced with the vein-solutions, and usually of later origin than the bournonite, arsenopyrite, and gold.

A third generation of pyrite, occurring near the base of the vadose zone in some mines—*e.g.*, Little Comet, New Lauraville, and All Nations—is occasionally rich in gold. Such pyrite is of secondary origin.

Sphalerite is present in many reefs, usually in small quantities. It is always later than the quartz and carbonates of the veins, but, with the exception of pyrite, it precedes the other sulphides and metals. As mentioned above, in specimens from the A 1 mine the sphalerite is included in bournonite, and in places is coated and veined by this mineral, and also gold. In one section a grain of pyrite is included in the sphalerite. In another specimen from above a fault between the No. 5 and No. 6 levels in the Rose of Denmark mine, small euhedral crystals of sphalerite are partly encrusted by gold.

Galena does not appear to be a common constituent of the veins in the dykes, but is often present in considerable amounts in the reefs outside the dyke belt, as at Store Point. Its relations with the other vein-minerals are generally obscure. At the Rose of Denmark mine it is of earlier generation than the gold, as the latter mineral encrusts and veins it.

Tetrahedrite is present in some mines—*e.g.*, Hunt's, Dempsey's, Rose of Denmark, New Loch Fyne, and Little Comet. It is distinguished from bournonite by its greyer colour, its lower specific gravity, its greater tendency to tarnish, and by the fact that it contains little or no lead. In specimens from the Rose of Denmark and Little Comet mines the gold was seen to be intimately admixed with tetrahedrite, and both were essentially contemporaneous.

Chalcopyrite is present in small quantities in most reefs. In one specimen from No. 8 level, A 1 mine, it is of later generation than the sphalerite and bournonite. At the Rose of Denmark mine it veins and replaces the tetrahedrite.

Carbonates (calcite, dolomite, and ankerite) are present in practically all reefs, whether in dykes or in sedimentary rocks. Normally, they line the vein-walls. Their subsequent origin to the quartz is well exemplified in many mines. Specimens from the Morning Star, A1, and Rose of Denmark dykes show ankerite and dolomite encrusting idiomorphic quartz crystals. In other examples—*e.g.*, Evening Star, Wood's Point, Little Comet, and Cohen's reefs—the quartz and carbonates are interlaminated, and are essentially contemporaneous.

The composition of the vein-carbonates is generally ankeritic or dolomitic, but calcite is sometimes present. An analysis of a delicate pink-coloured bladed vein-carbonate from the 220-ft. level of the Little Comet mine, Wood's Point. gave the following results. Appended for comparison are analyses of vein-carbonates form Bendigo and Kalgoorlie.

—	1	2	3	4
SiO_2	—	—	1.33	small
Fe_2O_3	tr.	—	0.73	1.27
FeO	6.49	3.87	5.86	8.63
MgO	18.20	19.46	16.96	15.86
CaO	29.04	29.70	29.79	28.88
MnO	0.47	0.67	tr.	—
CO_2	45.97	46.40	45.65	45.42
Totals ..	100.17	100.10	100.32	100.06

1.—Manganiferous ankerite, vein in Little Comet dyke. near rich gold. 220-ft. level. Analyst, N. R. Junner.

2.—Vein in serpentine, Hannan's Lake mine, Kalgoorlie (No. 42. p. 126).

3.—Carbonate crystals from vugs in a gold-bearing spur, stopes below 325-ft. level. Little 180 reef. Lansell's Little 180 mine. Bendigo, (No. 44. p. 20).

4.—Carbonate from vug in Nell Gwynne reef. North Bendigo mine, Bendigo. Analyst, J. C. Watson (No. 44. p 20)

The Little Comet specimen has the approximate formula 10 $CaCO_3$, 9 $MgCO_3$, 2 (FeMn) CO_3, which closely resembles certain so-called "Unusual Dolomites" * from the Simplon tunnel, which have the following formulæ, viz. :—

1.—3 $CaCO_3$. 2 $MgCO_3$. $FeCO_3$.
2.—4 $CaCO_3$. 3 $MgCO_3$. (FeMn)CO_3.

As will be seen in the sequel, the vein-carbonates in the Walhalla–Wood's Point belt in some cases appear to have caused deposition of the gold.

Albite is not an uncommon vein-mineral. It is usually pellucid and little altered. In one specimen from No. 2 level below main adit level, Rose of Denmark mine, the albite is included in carbonates, and is clearly of earlier generation. In another section, No. J10, of vein-quartz from No. 6 level in the same mine, the albite precedes the carbonates.

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* Neues Jahrb. Min. Geol, 1913.

In specimen J18, from No. 4 adit level, Working Miners' mine, Kevington, the albite and quartz are contemporaneous, and earlier than the carbonates.

Albite has also been noticed in quartz-veins in the Little Comet, New Loch Fyne, and Hunt's mines.

Viewed broadly, the order of deposition of the vein-minerals in this belt is as follows:—

Primary Zone	Quartz, albite, pyrite, and carbonates.
	Carbonates.
	Sphalerite.
	Galena and arsenopyrite.
	Arsenopyrite, bournonite, tetrahedrite, stibnite, and gold.
	Chalcopyrite and pyrite.
Vadose Zone	Arsenopyrite, pyrite, and calcite.
	Gold.

5.—Factors Causing Localization of the Gold.

A.—FAVOURABLE STRATIGRAPHICAL ZONES.

The "favourable stratigraphical zone" theory originated with Mr. Dunn, who claimed that at Bendigo there were present three stratigraphical zones in which the auriferous values were markedly different (No. 11)—

(1) The lowest zone of strata, which are exceptionally favourable to the occurrence of gold.

(2) A higher less auriferous zone.

(3) A still higher barren zone.

The late Dr. Hall (No. 19, p. 77), after a study of the Castlemaine goldfield, stated that "It appears that the auriferous strata of our Lower Silurian (Ordovician) rocks begins above the base of the apparently thick *Tetragraptus fruticosus* zone, and ranges at any rate as high as Phyllograptus does, but probably no higher."

Mr. T. S. Hart's observations at Daylesford (No. 22) led him to similar conclusions to those of Dr. Hall—namely, that the more important reefs are associated with Bendigonian and Lower

Castlemaine beds, and that the non-productive and barren zones are in beds on a higher horizon.

Mr. Dunn (No. 13, pp. 41, 42) has extended his "favourable zone" theory to the quartz reefs in the belt of country between Wood's Point and Jamieson. He says:—"Where the reefs are in a productive zone and in contact with dykes they are auriferous; but if the reefs occur in contact with dykes in barren zones of country rock there is no gold."

Notwithstanding the views of these able geologists, the difficulties with which the "favourable zone" theory has to contend are great. Rich auriferous reefs have been worked in rocks of pre-Cambrian age, in all zones of the Lower Ordovician except the Darriwill (which, apparently, is of very limited occurrence), in the Upper Ordovician, and in both Melbournian and Yeringian divisions of the Silurian. At Bendigo, according to Dr. Stillwell (No. 44, p. 54), highly profitable reefs occur outside the No. 1 area of Dunn (*vide supra*), and many reefs within this area have been unproductive.

Dr. Hall's contention that no gold occurs in rocks of Lancefieldian age has since been disproved.

In the belt considered in this paper the bulk of the gold has come from reefs within dykes, and it is difficult to see how the surrounding strata could have influenced the values. Further, more, rich auriferous reefs occur in beds having a wide stratigraphical range, at least from the base to the top of the Silurian. It is admitted that the best paying reefs occur within the Walhalla beds, but this is regarded as being an outcome of the geosynclinal structure of the belt.

B.—STRUCTURAL FEATURES—FOLDING AND FAULTING.

In many Victorian goldfields a close connection is evident between structural features—domed fractured anticlines, geosynclines, and faulting—and the broad localization of the gold.

At Bendigo, Mr. H. S. Whitelaw (No. 53, p. 47) claimed that there was a direct association of the gold shoots with the faults, and Dr. Stillwell's (No. 44, p. 56) and Mr. Pabst's (No. 38) observations strongly support this view.

At Castlemaine the best-paying reefs occurred near the crest and on the eastern limb of a domed geanticline.

At Ballarat East there was a close connection between the rich shoots and pockets of gold and the cross-courses. Numerous other instances of a similar nature could be quoted from other Victorian fields.

At least 90 % of the gold won from the Walhalla and Wood's Point belt has come from the central geosynclinal area. A glance at the map will show the marked localization of the dykes and chief mines in this central area. A moderate amount of gold has been won from the Royal Standard–Store Point line of reefs. However, these reefs occur in a well-defined structural zone of highly crumpled and faulted slates and phyllites.

C.—PETROLOGICAL CHARACTERS OF THE DYKES.

A detailed petrological examination of the dykes of this belt has brought to light the following interesting facts :—

(1) The richest auriferous reefs occur within or associated with rocks of dioritic or gabbroidal composition.

(2) More acid types — quartz and feldspar porphyries and granophyres—although fairly common, have yielded negligible quantities of gold.

(3) Small quantities of copper, nickel, and platinum and traces of gold and silver occur in all the more basic types—hornblende, peridotites, &c.—but no case is known of a payable auriferous quartz-vein being worked in them.

The most favourable rock for gold is one having a composition allied to that of the A 1, New Loch Fyne, and Morning Star types —*i.e.*, a diorite, porphyrite, or lamprophyre (camptonite) originally rich in brown hornblende.

Good gold was won from the Tubal Cain dyke—a rock of basaltic composition rich in augite and deficient in hornblende, but it is the only case known from this belt of non-hornblendic dyke rocks carrying auriferous quartz-veins.

Three dyke expansions which, although intersected by promising quartz reefs, have yielded little or no gold, are the Alabama, near

Matlock; dyke at "r" in "Jericho" on map; and Raymond's, near Gaffney's Creek. Microscopical examination of these rocks shows that they consist mainly of phenocrysts of feldspar—predominantly orthoclase, quartz, and altered hornblende in beautiful granophyric and microspherulitic intergrowths of quartz and feldspar.

D.—PROPYLITIZATION AND VEIN-ALTERATION.

Professor Gregory, in his description of the rocks near Wood's Point and Gaffney's Creek, states:—"It is probable that the gold will be found most in the diorites where propylitization has been apparently most thoroughly effected" (No. 17, p. 34).

The writer's study of these relations has convinced him that—

(1) The propylitization is independent of and earlier than the vein-alteration.

(2) The gold was introduced with the vein-waters and not with the solutions causing propylitization.

An investigation was undertaken to discover whether the gold values anywhere varied with the intensity of the hydrothermal alteration, but no specific instance of a direct relation between the two factors was discovered.

E.—VARIATION OF TEMPERATURE AND PRESSURE.

The nature of the propylitic and vein-alteration undergone by the dyke rocks strongly suggests that the now exposed portions of them were formed under conditions of moderate temperature and pressure.

Estimates of the amount of vertical denudation since the folding give 6000 ft. as a minimum figure, and, as the reefs are believed to have been formed at the same period as the folding, the above figure gives us an approximation to the depth below the then surface of the now exposed parts of the reefs.

Rapid variation of temperature and pressure would not be likely at these depths, and, even so, it would be insufficient to account for the extremely capricious nature of the gold-values in some mines.

The Long Tunnel mine, which reached a vertical depth of 3675 ft., is the only deep mine in this belt. Averaging the values throughout, a slight decrease is noted in depth. Such is probably due to variation of temperature and pressure.

F.—NATURE OF THE WALL-ROCK.

It has been demonstrated conclusively by members of the Geological Survey and others at Ballarat, Daylesford, Bendigo, and elsewhere in Victoria that certain bands of carbonaceous slate and pyritic seams have frequently a favourable effect on the auriferous values of the reefs intersecting or adjoining them.

In the belt considered in this paper local examples of the same nature are not uncommon. For instance, at the Long Tunnel mine, Walhalla, the presence of a graphitic or carbonaceous slate on the wall of the reef was considered a very good indicator of the proximity of gold. Mr. Baragwanath, who made extensive surveys of this mine, gives sections indicating that the proved main shoot of gold between the 1300-ft. and 3000-ft. levels follows very closely the theoretical intersection of the reef with a narrow band of strata (No. 3).

In the Morning Star mine, at the 500-ft. level, a local enrichment occurred on the eastern wall, where the quartz floor passed out of the dyke and cut a band of black slate.

At the A 1 mine, between the 850-ft. and 1000-ft. levels, the reefs normally intersect two dykes and much hard sandstone and quartzite, and sometimes near the lode walls they cut across bands of black slate. Although auriferous throughout, the reefs were richer within the green-mottled, highly-carbonated, mica-hornblende-lamprophyre dyke—the "kindly country rock" of the miners—and in the slates, than within the quartzite.

Reefs occupying fault-planes which intersect and displace dykes are common in the northern portion of the belt. Considerably enriched values at and close to the intersections of the reefs and dykes are the rule in such cases. However, none of these have been worked in the zone of primary values, and it can be demonstrated in many cases that the concentration of the gold at these points is due to secondary enrichment.

G.—REPLACEMENT.

Throughout this belt the richest quartz reefs in the zone of primary values, whether within dykes or in Silurian sediments, are of the laminated type. Microscopic study of thin sections of these reefs by the writer has convinced him that they are largely of replacement origin, as Dr. Stillwell (No. 44, p. 34) has ably demonstrated for the laminated quartz reefs at Bendigo.

An examination of the auriferous quartz from the Long Tunnel, Fulton's, Harbinger, and Star of the West mines, all of which occur within sedimentary rocks, shows a marked aggregation of the gold—which is usually very finely divided—along the laminæ, the carbon, arsenopyrite, and pyrite of which appear to be the main precipitating agencies for the gold. Much of the quartz is of replacement origin, and the laminations are believed to represent unreplaced flakes and films of the wall-rock, impregnated and encrusted with dusty and minutely-crystallized pyrite and arsenopyrite.

In reefs within dykes the quartz is sometimes laminated. Often the central portion of the reef is composed of white quartz slightly laminated, while the marginal variety is well laminated and frequently dark in colour, due to finely-divided sulphides.

Ankerite or ferriferous dolomite normally lines the vein-wall.

The most obvious characteristic of the gold occurrence in the reefs in dykes is its marked localization in the quartz adjoining the vein-walls. Microscopical examination has shown that this latter quartz has originated by replacement of the wall-rock. Partially replaced fragments and undigested residues of dyke material are common in the quartz. Finely-divided pyrite and some arsenopyrite are extensively developed in the process of replacement. That these sulphides have played an important part in precipitating the primary gold is evident from the way in which the gold encrusts and replaces them in specimens from the Morning Star, New Loch Fyne, A 1, Rose of Denmark, and Little Comet mines (*vide supra*, p. 207). In other cases, galena, sphalerite, vein-carbonates, and rock residues have apparently caused the precipitation of the gold. The marked concentration of the gold in the marginal quartz of replacement origin is believed to be due to the greater concentration of the above-mentioned precipitants in these parts of the veins.

The dykes themselves are apparently capable of precipitating the gold from the vein-solutions, for certain specimens from the 850-ft. level, A 1 mine, show facings of gold with little or no quartz or sulphides on joint planes near a rich floor in the mottled mica-hornblende-lamprophyre referred to above.

Examples of gold deposited on carbonates (ankerite, dolomite, and calcite) are not common. The writer has seen specimens of dolomite from the A 1 mine with specks of gold adhering to them; of calcite from the Georgia and Unknown mines with gold included in and intermingled with it; and of ankerite from the 220-ft. level, Little Comet mine, Wood's Point (*vide* microphotograph No. 21), encrusted and veined with leaf gold. However, the gold in this last-named specimen and in the ones from the Georgia and Unknown mines is possibly of secondary origin.

H.—SECONDARY ENRICHMENT.

Examples of the concentrating effects of secondary enrichment on the gold by gravitation and solution are extremely common throughout this belt. Perhaps the best case of great mechanical concentration at and near the surface is the Royal Standard mine which yielded considerably more than £50,000 worth of gold from quartz averaging about 2 oz. to the ton from the surface to a depth of 70 ft. Very little gold has been unearthed from below this level.

Another illustration is the Specimen mine, near Ten-Mile, the quartz from which averaged nearly 51 oz. to the ton from the surface to a depth of 32 ft., and became unpayable below 100 ft.

Examples of rich pockets and shoots of gold near the base of the zone of surface decomposition, and particularly at points where the descent of auriferous solutions has been checked, are plentiful. The types of obstruction which appear to have been particularly favourable to the localization of the gold are as follows:—

(1) Ledges formed by small rolls in the dykes and reefs and by small faults intersecting them—*e.g.*, Georgia and Knowle's dyke, &c.

(2) Flat or rising veins proceeding from the dykes into the strata—*e.g.*, Morning Star dyke. These veins obstruct the descent of auriferous waters along the dyke walls.

(3) The intersections of steeply-dipping veins with flat or rising ones—*e.g.*, Little Comet and Leviathan mines. The Morning Star dyke provides what is believed to be the best illustration of vadose shoots of gold. According to Mr. O. A. L. Whitelaw (No. 55, p. 16), "the Age of Progress reef was worked for a length of 1500 ft. along the western wall, and Cherry's reef for 1100 ft. on the eastern wall." These reefs were relatively poor in the centre of the dyke, but were extremely rich on the walls, as the following recorded returns for the years 1864 and 1865 show:—

27,933 tons of quartz yielded 94,075 oz. of gold.

Summary of the Factors Causing Deposition and Localization of the Gold.

1. Structural features are believed to be far more important than stratigraphical zones in causing the localization of the gold.

2. Physical features, such as variation of temperature and pressure, apparently have played an unimportant part in causing the deposition of the gold.

3. Payably auriferous reefs are found in or associated only with dykes of dioritic or gabbroidal composition.

4. The main deposition of primary gold in the reefs appears to have been due to the chemical precipitation of the gold in the ascending auriferous solutions by the previously-formed sulphide minerals—pyrite, arsenopyrite, sphalerite, and galena—and by carbonaceous and other rock residues, and occasionally by the vein-carbonates.

5. Secondary processes—denudation, gravity, solution, and re-deposition—have re-concentrated the primary gold-forming important shoots and pockets of gold within the vadose zone.

6.—THE RELATION OF VICTORIAN AURIFEROUS REEFS TO IGNEOUS ROCKS.

Auriferous quartz-veins occur within or directly associated with igneous rocks of various types in Victoria. They occur in granodiorite at Maldon, Dargo, Mount Wills, Hillsborough, Warburton. and elsewhere.

Auriferous pegmatites are known from Huon's Lane (in North-Eastern Victoria), Nuggety Reef (Maldon), and from Lintons.

Gold-bearing reefs occur in sericitized and silicified quartz–feldspar–porphyry dykes at Diamond Creek, Foster, Blakeville, Maldon, Stawell, Kinglake, Queenstown, Warburton, &c.; and in other localities, as at Sebastopol, near Ballarat, and at Maryborough, they are closely associated with similar dykes.

Few of the mines occurring within the above-mentioned rocks have yielded large quantities of gold. They are of scientific interest, but rarely of economic importance.

Whenever there is a direct connection between dykes and auriferous quartz-veins, as is the case on many of our goldfields, it is generally with rocks of intermediate to basic composition, In the Walhalla-Wood's Point belt, as previously mentioned, all the best reefs are associated with rocks of dioritic or gabbroidal composition, and the reefs connected with more acid and more basic types have yielded little gold.

Another very important and interesting belt where similar relations exist is that extending through Creswick, Clunes, Talbot, Maryborough, Dunolly, and Wedderburn—the fabulously rich alluvial belt of our colony.

Closely associated with the reefs in this zone are two distinct types of dykes—

(1) Acid types—quartz and feldspar porphyries.

(2) Intermediate to basic types—diorite and gabbro porphyrites and lamprophyres.

The reefs related to the first class of dykes have yielded little gold. The second class occur, as in the Wood's Point area, in two ways, viz. :—

(*a*) As lenticular expansions or pipes—*e.g.*, Rheola, Talbot, Spring Hill, and Central Leads (near Smeaton), and at Tarilta and Metcalfe, some miles to the east of this belt.

(*b*) As narrow dykes at Wedderburn, Rheola, Moliagul, Dunolly, Maryborough, and Amherst.

The rocks of the dyke bulges are normally dioritic in composition, and frequently show green chloritized phenocrysts of hornblende and pink feldspar in hand specimen. In thin section they are seen to be closely allied to the Morning Star and New Loch Fyne types described above. They are characterized by much-altered—chloritized, carbonated, and epidotized—brown hornblende, chloritized and sericitized plagioclase, and clear quartz in a ground-mass which has been re-crystallized generally in the form of a micrographic intergrowth of quartz and feldspar. The characteristic minerals of the propylitic *facies*—namely, pennine, epidote, massive carbonate, pyrrhotite, and pyrite—are all present. In most cases these rocks are closely associated in the field with quartz-feldspar-porphyry dykes, and it is probable that they are differentiation products of a common magma.

Although quartz reefs are uncommon within these dyke expansions, they are numerous in the contact rocks, and rich alluvial gold has been won from the vicinity of practically all of them.

The gullies heading towards the Talbot dyke expansion were particularly rich near the dyke, and the same is true at Tarilta.

According to Professor J. W. Gregory (No. 16, p. 10), "The bed-rock at the Spring Hill and Central Leads is penetrated by a broad dyke which is closely related to the rock of the dyke in the New Loch Fyne mine at Matlock, and it is not surprising that it has caused the deposition of the gold in the adjacent slates, and that the old river gravel beside it should be rich in gold."

At Rheola outcrops of hornblende diabase and diorite porphyrite, which have been altered along their contact by the granodiorite, are not uncommon. Numerous lamprophyre dykes are also present. The alluvial in the vicinity of these rocks was notoriously rich in large nuggets.

The narrow dykes are in the main much altered—carbonated, chloritized, and sericitized—hornblende and biotite lamprophyres —camptonite and spessartite. Fairly rich auriferous reefs occur within or adjacent to such dykes at Maryborough, Dunolly, Landsborough, Rheola, and Wedderburn.

Other areas in Victoria where gold-bearing reefs are known to be intimately associated with dioritic and gabbroidal rocks are Queenstown (near Melbourne), Granite Flat, and Dargo. In many other places in Victoria the nature of the dykes associated with the auriferous quartz reefs has not been investigated. Igneous intrusions of a more basic character than the abovementioned are rarely if ever connected with auriferous reefs in Victoria.

Hence it is concluded that the favourable type of igneous intrusion for gold reefs in this State is one of dioritic or gabbroidal composition. Current belief connects our main goldfields with granodiorite intrusions. Viewed broadly, this is true, but it is generally with the intermediate and basic differentiates from the same magma from which the granodiorite has been derived that the most intimate connection is apparent.

7.—Fineness of the Reef Gold.

The gold saved by amalgamation varies in fineness from about 800 (as in the case of the Lady Vera, near Fulton's Creek, and the Morning Star) to 960 or 970 (as in the Franklin, Eldorado, and A 1 mines).

Apparently the nature of the vein-sulphides has influenced the fineness of the gold. Where stibnite is the predominant sulphide —*e.g.*, Leviathan and Royal Standard mines in this belt, and at Alexandra and elsewhere in Victoria—the gold is invariably of good quality.

Where the vein-sulphides are chiefly sulpharsenides and sulphantimonides — *e.g.*, bournonite, tetrahedrite, jamesonite, and arsenopyrite—the gold is usually of good quality, as is the case in the A1, Eldorado, Wallaby, All Nations, Sir John Franklin, Dempsey's, Georgia, and Little Comet mines. The Long Tunnel gold, however, was of relatively poor quality (820–860), although associated with arsenopyrite, bournonite, and pyrite. Where galena and sphalerite predominate in the veins the gold is rarely of good quality—*e.g.*, Rose of Denmark (845–880), and the New Loch Fyne (830–870).

In general, the average fineness of the gold from reefs within dykes is not less than that of the gold from reefs in the sedimentary rocks.

Descending vadose waters apparently have refined the gold, as almost invariably the gold from shallow workings of less than 300 ft. is of good quality—*e.g.*, Unknown, Eldorado, Royal Standard, Little Comet, Georgia, &c. In the Rose of Denmark mine the gold from the primary zone was of lesser fineness than that from near the surface. Dr. Don's analyses of Victorian vein-gold indicate that on the whole the average fineness of the gold in the vadose region is appreciably greater than that from the primary zone in the same district (No. 10, pp. 607, 608).

PART III.—SECONDARY ENRICHMENT IN THE MINES BETWEEN WOOD'S POINT AND JAMIESON.

1.—Introductory Remarks.

On glancing through the geological and mining literature of Victoria, one is struck by the paucity of references to undoubted cases of secondary enrichment in our auriferous ores. On looking for a reason for this. three possibilities are suggested—

1. The scientific investigation of the problem has been neglected. Certainly, no detailed study of the question has been made on any of our mining fields, and the few scattered references to the subject in the literature are, on the whole, brief and inconclusive. Furthermore, the upper oxidized zones of most of our mines were worked out in the early days of gold mining before the *rôle* of secondary enrichment in re-concentrating the gold was understood, and consequently there are very few facts relevant to the subject preserved in the literature.

2. Difficulty of recognition.

The gold won from the more important mining fields of Victoria is noted for its free-milling character. The chemically unstable sulphides of copper, lead, iron, and zinc, which afford elsewhere excellent criteria for determining secondary enrichment, are associated normally with the gold in small quantities, but their occurrence in large amounts is exceptional. Complex refractory auriferous ores occur at Bethanga and Cassilis, in the north-east of Victoria, but they are of no great economic importance.

3. The effects of secondary enrichment on our auriferous quartz-veins may have been so small as to have been of no economic importance. This, the writer believes, is a fairly widely accepted view.

The purport of this section of the paper is to show that many mines of this belt have suffered important enrichments by mechanical concentration and chemical migration of the gold contained in the reefs.

2.—Secondary Enrichment.

A.—DEFINITION.

To avoid misconception, it would be well to define precisely what we mean by secondary enrichment. This term is used here, firstly, for the enrichment at and close to the surface, by the mechanical concentration of the gold derived by denudation from the former upward extension of the auriferous quartz-veins; secondly, for the enrichment in the vadose zone by the breaking down of the auriferous sulphides by descending surface waters, which carry away the base metals and their salts in solution, leaving the gold in situ; and thirdly, for the enrichment in the vicinity of the base of the vadose zone by the solution of the gold from and near the surface by descending waters and its subsequent re-deposition in more concentrated form at a lower depth, which, in most mines in this belt, is between 150 ft. and 300 ft.

B.—PREVIOUS LITERATURE.

Mr. H. A. Thompson (No. 49, p. 248) suggested that the decrease in gold-values as mining became deeper was due to the surface alteration of the dykes.

Mr. R. A. F. Murray (No. 35, p. 123), who was a loyal supporter of the permanence in depth of the auriferous values in these veins, recognized that secondary enrichment had played some part in localizing the gold. He says, speaking generally of Victoria:—

"On the average, richer quartz has been obtained from the surface portions of the reefs generally than has been met with in the deeper levels."

And again—

"We must consider also the reactions produced by meteoric waters proceeding from the surface downwards, and this process is partly one of decomposition and partly one of concentration."

Mr. O. A. L. Whitelaw (No. 55, p. 14), dealing with the Wood's Point area, states that

"It is a commonly-accepted belief among miners in the district that decomposition has had considerable influence upon the occurrence of the gold. The greasy decomposition product, 'mutton fat,' is regarded as one of the best indications of the proximity of gold."

C.—THE MECHANICS OF SECONDARY ENRICHMENT.

Nowhere in this belt is there found any evidence of marine conditions later than the folding of the Silurian sediments—*i.e.*, since Devonian times.

No exact figure of the amount of vertical denudation since this period of folding and intrusion of the dykes and auriferous quartz-veins can be arrived at, but estimates from vertical sections constructed from dips give 6000 ft. as a minimum figure.

Postulating the extension of the auriferous quartz-veins to the surface at the time of their formation, which seems reasonable, what, then, has become of the gold released from these reefs? Some of it has been carried away by past and present-day streams. The sub-basaltic gravels at Moondarra, near Walhalla, and on the Thomson–Aberfeldy divide have furnished little gold, and, although the alluvial terrace deposits and gravel beds of the present-day streams have locally yielded rich results, on the whole they have been much poorer than similar deposits on other Victorian goldfields.

The factors that have determined the ultimate fate of the gold derived from the former upward extensions of these reefs are as follows, viz.:—

(1) The relative rates of denudation and solution of the gold.

(2) The degree of permeability of the dykes, sediments, and quartz-veins to surface descending waters.

(3) The chemical nature of these waters.

(4) The amounts of sulphides present in the quartz-veins and the dykes and the nature of the products derived by their decomposition.

(1) If denudation progresses faster than the solution of the gold by surface descending waters, then a large part of the gold will be washed away into the gullies and streams before it has had time to dissolve. In the ideal case we should expect fairly rich alluvial deposits and practically no change in the tenor of the quartz from the surface down to the zone of primary sulphides. If, on the other hand, the chemical leaching of the gold proceeds at a more rapid pace than the denudation, we should have in the ideal case little or no alluvial gold, a barren or poor surface zone,

and a considerable enrichment near the base of the vadose zone. As the degradation of the rocks proceeds, the gold in this enriched zone will in its turn be dissolved and re-deposited at a lower level. Consequently, in the extreme case, we should get the whole of the gold from the former upward extensions of the reefs concentrated near the water-level, with poor values above and the unenriched ore below. No example of this type is known from this belt.

If denudation and solution keep pace one with another, the outcome should be payable alluvial, payable or slightly enriched surface ore, and an enrichment near the bottom of the vadose zone. This state of affairs is well illustrated in many of the mines in this belt—*e.g.*, All Nations, Morning Star, Hunt's, New Loch Fyne, &c.

(2) The degree of permeability of the dykes, &c.—That the dykes and quartz-veins have provided the easiest channels for descending waters is proved by the much greater depth of decomposition in them than in the surrounding sediments. In many dykes, more especially the dyke expansions, the waters appear to have proceeded by certain localized channels, and did not permeate the whole of the dykes. For example, in the Morning Star, New Loch Fyne, Luck's All dykes, &c., numerous patches of hard, undecomposed rock outcrop at the surface, although in all these cases, at depths between 200 ft. and 300 ft., the dykes are greatly decomposed.

Frequently the walls of the dykes have provided the readiest conduits for the surface waters, and in many mines rich patches of gold, often free from quartz, occur along the dyke walls—*e.g.*, May Moon, Knowle's, Waverly, Georgia, Sutcliffe's (near Matlock), and Morning Star mines.

In certain other cases finely-divided gold and films of gold are found along bedding planes and fractures in the country-rock near the surface. One specimen of soft mudstone from near the A 1 mine shows finely-divided gold without quartz on a bedding plane, and in another specimen from the Champion mine, near Ten-Mile, similar gold, free from quartz, occurs on a bedding plane in association with limonitized pyrite cubes. A piece of Cohen's dyke, from the 150-ft. level in the Long Tunnel mine, in the Ballarat School of Mines collection, shows free gold without any quartz on a joint plane or fracture in the rock, and similar examples have been seen in the A 1 dyke, near the surface.

The downward descent of the auriferous waters may be checked by impervious barriers, such as faults, rolls in the reefs and dykes, cross-veins, and other structural features, and the bulk of the gold will be deposited in close association with these barriers. Such gold will, in general, be prevented from migrating downwards in solution, and will, in the course of time, reach the surface. As a case in point, the famous Royal Standard reef consisted of the dissected remnants of a bedded synclinal vein, the trough of the reef being about 70 ft. from the surface (No. 57, p. 20). The mode of occurrence of the gold and the wonderful richness of the reef strongly suggest that the structure acted as a barrier to descending auriferous waters.

(3) The chemical nature of the vadose waters.—Variations from time to time in the chemical nature and amounts of the vadose waters will naturally affect the amount of gold going into solution. If no solvent is present, then no gold will be dissolved, and consequently in time it will reach the surface by denudation.

Of the solvents for gold, it is believed that free chlorine derived from the attack of sulphuric acid on manganese dioxide in the presence of soluble chlorides has been most potent. Sulphuric acid is formed by the oxidation of iron pyrites, which is present in all the dykes and most quartz-veins. Hydrated oxide of manganese in small quantities is ubiquitous near the surface. Almost every piece of quartz from near the surface contains stains and veinlets of psilomelane. Nearly all the dykes contain small amounts of MnO—*e.g.*, Morning Star, 0.14 %; New Loch Fyne, 0.15 %; and one specimen of the A 1 dyke, 0.23 %. Furthermore, the vein carbonates—ankerite, &c.—are usually manganiferous. One specimen of ankerite from the Little Comet mine gave, on analysis, 0.47 % MnO. Soluble chlorides are present in nearly all vadose waters.

D.—ENRICHMENT BY MECHANICAL CONCENTRATION AT AND NEAR THE SURFACE.

The chief criterion used in determining this type of enrichment is the occurrence of very rich surface-values, decreasing fairly rapidly in depth.

Several mines in this belt were wonderfully rich right at the surface, but failed to maintain their reputation in depth. For example, gold was seen glittering on the surface outcrop of the Royal Standard mine by the discoverers when 100 ft. away from it. The first recorded crushing from this mine yielded 2934 oz. of gold from 300 tons of ore, equal to about 9¾ oz. per ton. The total recorded yields up to November, 1866, are about 13,718 oz. of gold from 7000 tons of quartz obtained from the surface to a depth of 70 ft.

The first recorded crushing from the Specimen mine, near Ten-Mile, gave 610 oz. 11 dwt. of gold from 12 tons of quartz, from depths 0–30 ft. At a depth of 100 ft. 133 tons of ore yielded 458 oz. of gold. A lower tunnel cut the reef, but apparently it was poor, as work was soon discontinued.

Dempsey's reef, Gaffney's Creek, was extremely rich near the surface. In 1861, 7 cwt. of quartz from near the surface gave 153 oz. of gold, and, from a depth of 23 ft., 8 tons of quartz yielded 370 oz., and 100 tons averaged 15 oz. per ton. At 80 ft. the average tenor of the quartz had fallen below 10 dwt.

In 1865 some patches of extremely rich ore were taken out of the Eldorado mine from the surface to a depth of 30 ft., as will be seen by the following figures:—

June, 1865.—5 tons of ore gave 90 oz. of gold, 0–30 ft.

Sept., 1865.—9 tons of ore gave 448 oz. 12 dwt. of gold, 0–30 ft.

Dec., 1865.—7 tons of ore gave 64 oz. 10 dwt. of gold, 0–30 ft.

From 1864 to 1895, inclusive, 4720 tons of ore from this mine yielded 5333 oz. 13 dwt. of gold from the surface to a depth of 200 ft.

In the New Loch Fyne mine 2 tons of ore from the surface produced 73 oz. of gold. At depths between 40 and 55 ft. 372 tons of quartz yielded 1791 oz. of gold in 1864. No ore from greater depths ever approached this richness.

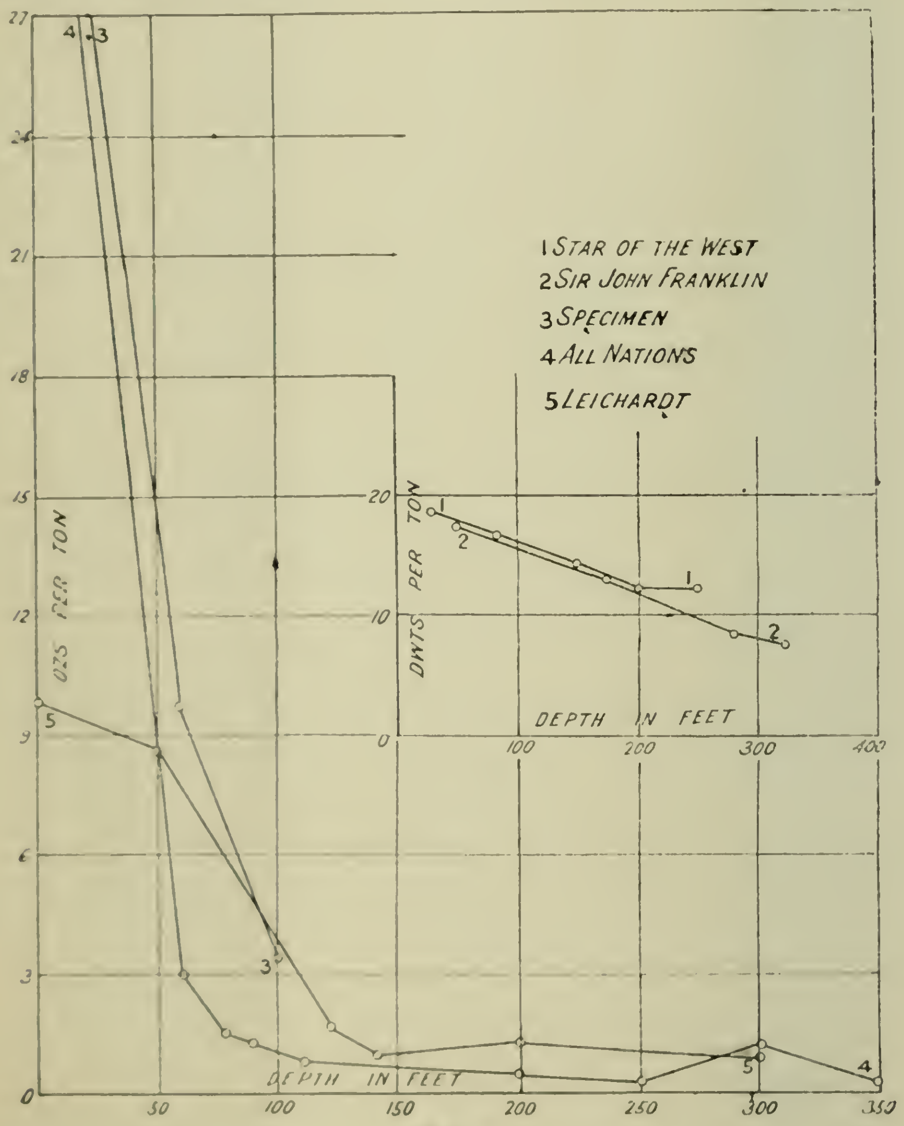

FIG. 5.

GRAPH.

Illustrating enrichment in auriferous values at and close to the surface.

The richness of the ore from the Leichhardt mine, Stander's Creek, near the surface, and its impoverishment with depth, are well illustrated by the following yields given by Mr. O. A. L. Whitelaw (No. 55, p. 29):—

Depth	Ore Crushed.	Yields of Gold
	Tons.	oz. dwt
Surface	15	146 0
0–100 ft.	24	208 0
120 ft.	457	767 10
130–150 ft.	905	751 10
200 ft.	126	152 5
300 ft. (No. 3 level) ..	—	Av. 16

The first recorded crushing from the All Nations mine produced 165 oz. of gold from 1¾ tons of superficial ore. Some rich quartz was worked to a depth of 120 ft., but below this depth the total ore treated averaged less than 1 oz. per ton.

Again, in March and June, 1865, 295 tons of ore from depths of 0–30 ft. in Hunt's dyke yielded 633 oz. 17 dwt. of gold. At a depth of 80 ft. the tenor of the ore had fallen to less than 7 dwt.

The Never Mind, Johnson's, and Republic reefs, near Wood's Point, and the Shakespeare reef, near Gaffney's Creek, were all rich at and near the surface, but became unpayable at depths less than 200 ft. The first crushing from the Never Mind reef gave a return of 93½ oz. of gold from 10 tons of ore. According to Mr. D. B. Walker (No. 52, p. 12), £33,000 worth of gold was extracted from this reef between February, 1866, and November, 1867. Practically the whole of this gold came from an open cut 50 ft. deep. Below this depth the ore was not payable.

Other mines, such as the Sir John Franklin, Star of the West, and Sailor Bill's, show a progressive decrease in values from the surface downwards without any great marked surface enrichment (*vide* graph, fig. 5).

E.—ENRICHMENT IN THE LOWER PART OF THE VADOSE ZONE.

(*a*) *Criteria for Recognition.*—Numerous instances of enrichment in the auriferous values have been noted in the mines of this belt in the vicinity of the base of the zone of surface decomposition, which varies from a depth of 100 ft. or less to more than 350 ft. In most cases the enrichment can be proved to be due to the leaching of the gold from the upper portions of the veins by descending surface waters and its re-deposition in more concentrated form at lower levels.

The criteria used for determining this type of enrichment are as follows, viz. :—

(1) Statistical; the occurrence of considerably enriched values near the base of the vadose zone.

(2) The mode of occurrence of the gold.

The gold from such enriched patches or zones in the lodes occurs in the following ways :—

(*a*) In mossy and fern-like growths; in botryoidal form; in crystals; and as strings and veins filling cracks in friable quartz and country-rock. Such gold is normally associated with limonite and psilomelane, and sometimes with native copper, malachite, "mutton fat," and rarely with secondary sulphides.

(*b*) As nuggety and finely-divided gold, frequently free from quartz, on ledges and shoulders on the dyke or vein-walls; at the intersection of steeply-dipping and more or less flat veins, and on relatively flat faults displacing the dyke or reef. The gold from these patches is sometimes coated with limonite and psilomelane or arsenopyrite, and at other times it is deposited on pyrite or arsenopyrite.

There can be no question of such gold being formed in any other way than from descending surface waters.

Fig. 6 illustrates graphically this enrichment in the lower portion of the zone of surface decomposition in certain mines.

The statistics from which the graphs were constructed were mostly culled from the quarterly reports of the mining surveyors and registrars of Victoria. The writer is quite aware that the recorded values of the ores are not in all cases true reflections of their average tenor. In certain mines some of the ore is hand-picked before crushing. In others a good deal of mullock is crushed with the quartz. Again, in many cases only the richest ore is mined. These factors, and the practice adopted by certain mine managers of keeping back some of the richer specimens from one crushing to equalize or boost others, all tend to place a false value on the ore mined. Nevertheless, the writer

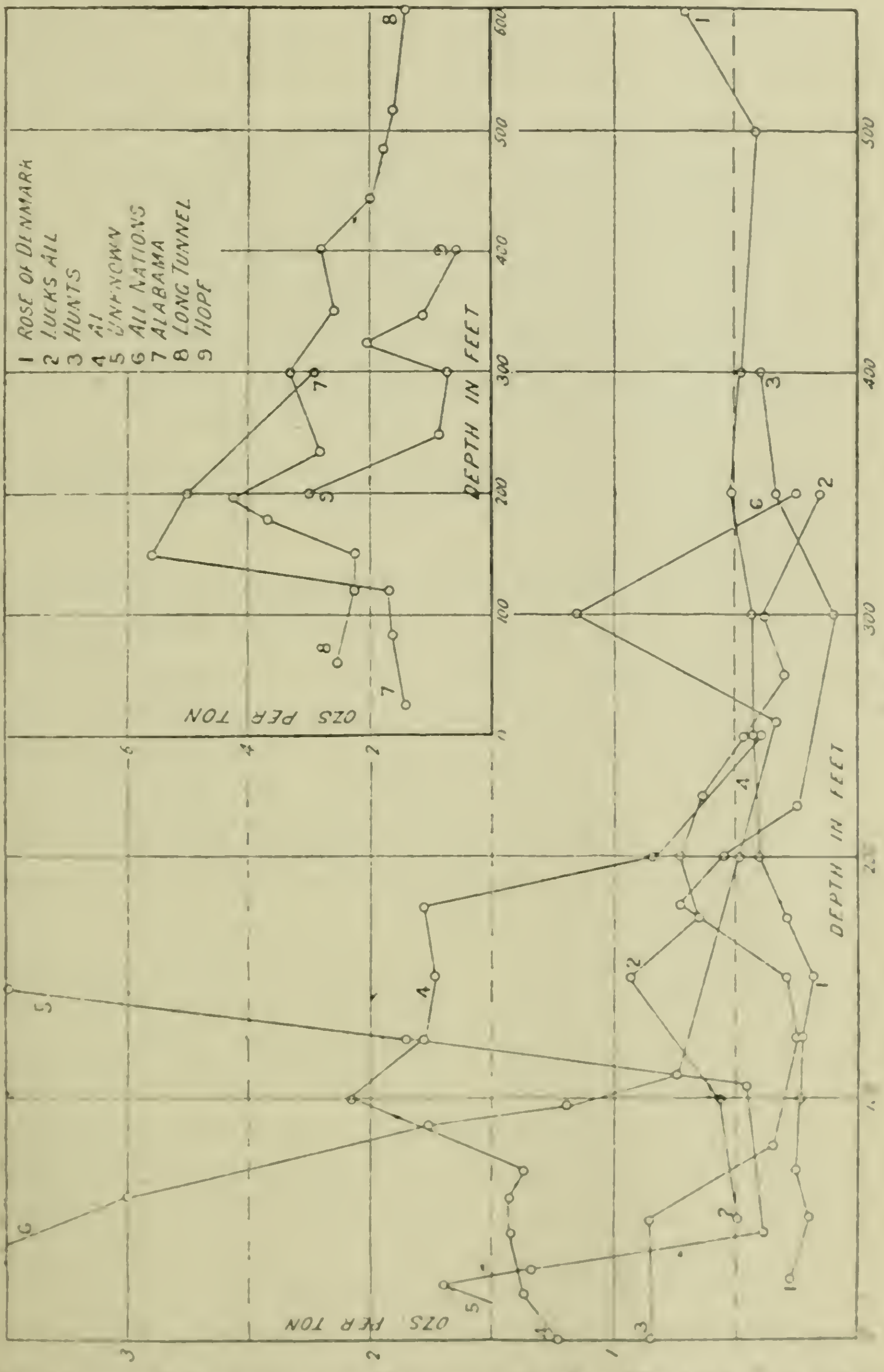

FIG. 6.
GRAPH.
Illustrating enrichment in auriferous values in the lower part of the valose zone.

is of the opinion that the graphs give a fairly close approximation to the true values of the ore at the various depths indicated on them. Care has been taken to exclude as far as possible yields from small parcels of quartz, unless they are taken in conjunction with larger crushings from the same depth, also those returns where a wide range in depth is recorded, and others, again, where the depth is not given, or is uncertain.

The general conclusion to be drawn from the graph is that in certain mines—*e.g.*, Alabama (Ten-Mile), Luck's All, A 1, Long Tunnel, Hope (Morning Star), All Nations, and Unknown—enrichments, in some cases of considerable economic importance, have taken place at depths varying generally between 100 and 300 ft.

In the A 1 mine the enriched ore occurred at depths between 100 and 180 ft. from the surface ; in the Long Tunnel, at about 200 ft. ; in the Alabama, between 140 and 200 ft. ; and in Hunt's, between 180 and 200 ft.

(*b*) *Detailed Account of Enrichment by Solution of the Gold and its Re-deposition at Lower Levels.*—Georgia mine, Railway Creek, near Enoch's Point.—Two dykes, about 10 ft. apart, dipping at high angles, 70°–80°, to the west are seen in this mine. They cut across the strata, which dips at angles varying between 40° and 50° to the east, at about 60° in dip and 40° along the strike. The western dyke, on which the bulk of the work has been done, averages 3 ft. in width, but enlarges locally to 10 ft., and pinches elsewhere to a few inches in width.

The characteristic flat veins of the narrow dykes are well exemplified in this mine. They average 2 to 3 in. in width. In places flat veins of coarse calcite and arsenical pyrites replace the usual quartz-ankerite veins. These flat veins or "floors" normally stop sharply at the dyke wall. They were worked in the early days of this field, between 1868 and 1881, and averaged about 3 dwt. of gold per ton. Thin veins of well-crystallized calcite, with a little iron and arsenical pyrites, occur in places between the walls of the dyke and the contiguous strata.

Small dip-slip faults displace the dyke a few inches, but rarely more than 6 in. At the intersection of the hanging wall of the dyke with these displacements, patches of coarse and of fine gold are frequently found (*vide* fig. 7).

Sometimes the dyke departs locally from its normal dip and rolls a few inches to the east, as in fig. 8. In such cases there is usually a ledge or shoulder of hard sandstone with the dyke wall.

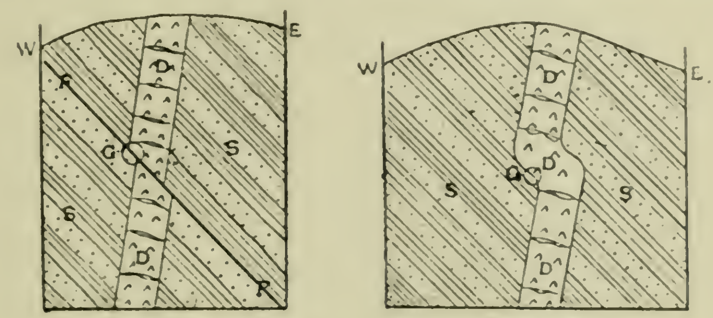

Fig. 7. Fig. 8.

SKETCH SECTIONS ACROSS THE GEORGIA DYKE, NEAR ENOCH'S POINT

Showing localization of patches of gold—"G." "D" = lamprophyre dyke with flat quartz veins; "S" = Silurian slates and sandstones; "F" = fault.

These ledges are favoured places for the finding of patches of nuggety and fine secondary gold.

Coarsely crystalline gold in calcite is sometimes found in this mine where the flat veins of calcite and arsenopyrite intersect the hanging wall.

Thanks to the courtesy of Mr. F. Higgins, of Enoch's Point, the writer had excellent opportunities of studying the gold-occurrence in the Georgia mine and of examining numerous specimens taken from the above-mentioned patches on the ledges and fault-planes.

The gold from these places occurs in various forms—

(1) As nuggets practically free from quartz, and often coated with hydrated oxide of manganese and secondary arsenical pyrites—so-called "black gold." The largest nugget from this mine weighed about 36 oz., but several others up to 5 oz. in weight were unearthed. This nuggety gold is absent in the veins within the dyke, and is confined to the above-mentioned ledges and fault-planes. Two nuggets of black gold, free from quartz, in size and shape of a wooden match-box, were seen by the writer. They came from between the walls of the dyke and surrounding sediments, and their shape obviously had been determined by that of the walls.

(2) As loose fern and moss gold, which is often well crystallized and usually coated with pyrolusite and arsenical pyrites and red hydrated oxide of iron.

(3) As beautifully-crystallized gold — normally in form of octahedra or dodecahedra, and more rarely as cubes, sometimes bright, but more often coated by secondary arsenopyrite and psilomelane. Crystalline gold also occurs in calcite along the walls of veins within the dyke.

(4) As botryoidal gold deposited on earthy arsenopyrite.

(5) As finely-divided loose gold and coating arsenopyrite.

(6) As black gold.

Where the gold is associated with calcite it is almost invariably well crystallized, and frequently nuggety. One specimen of the gold from one of these ledges was in the form of a rosette of crystals, and was attached to a crystal of quartz.

Knowle's Dyke, Knowle's Creek, near Enoch's Point.—Knowle's dyke averages up to 6 ft. in thickness, and dips at a high angle to the east. It cuts across the strata, which dip here at about 40° to 50° to the east in strike as well as in dip, as in the Georgia dyke. The dyke carries the usual flat leaders of quartz, but in general they were found to be unpayable.

Some of the salient features of the gold-occurrence in this mine are as follows, viz. :—

(1) Practically all the gold came from the foot-wall of the dyke at its intersection with small bedded fault-planes, and from ledges where the dyke has altered its course locally, in exactly the same manner as in the Georgia mine.

(2) Several nuggets of fairly large size were unearthed from this mine. Mr. F. Higgins informs the writer that the first of any note, 25 oz. in weight, came from a depth of 150 ft., and that they were found to a depth of 300 ft. from the surface. The largest nugget found in this belt, 168 oz. gross and 150 oz. fine, came from this mine at a depth of 200 ft.

(3) None of this nuggety gold came from within the dyke; all of it came from the walls of the dyke.

(4) The nuggets were very free from quartz, and were often coated with secondary earthy arsenopyrite and psilomelane, and occasionally limonite.

(5) Quite a considerable amount of finely-divided crystalline and fern gold was found with the nuggets.

(6) Several nuggets, many of which were of the "black gold" type, were found in Knowle's Creek.

Waverly Dyke, Wood's Point.—Mr. Renwick, of Wood's Point, informed the writer that he obtained rich patches of coarsely-crystallized gold associated with little or no quartz on ledges near the surface on the hanging-wall of the dyke formed by small rolls.

Such ledges seem to be favoured places for the deposition of the gold, for Mr. O. A. L. Whitelaw (No. 57, p. 24) says, speaking of the Republic mine, near Wood's Point—

"The reef makes numerous rolls or pitches in a general northerly direction, and it is upon the 'shoulders' thus formed that the richer patches of gold have been found."

Again, according to Mr. R. A. F. Murray (No. 37, p. 43)—

"The quartz carrying the best gold at the Rose of Denmark mine seems to ride on slightly projecting ledges of the slate rock on the footwall."

May Moon Dyke, All Nations Mine, Matlock.—Rich patches of gold were unearthed by Messrs. Lawson Bros. from the wall of the May Moon dyke at a depth of between 150 ft. and 200 ft. One nugget, weighing more than 100 oz., was obtained by them at a depth of about 200 ft. between the dyke-wall and the country-rock ; it was associated with much limonite, and practically free from quartz. According to Mr. O. A. L. Whitelaw (No. 55, p. 26), "The greater part of the gold is obtained not in the quartz leaders traversing the dyke, but in a brown clay or 'dig' which lies between the contact of the dyke and the sedimentary beds. The gold is said to be very often dissociated from quartz."

Sutcliffe's Mine, North-West of Matlock.—The workings in this mine are on a narrow dyke averaging 4 ft. in width, and dipping to the east at about 80°. The dyke is greatly decomposed to a depth exceeding 300 ft. Some rich patches of nuggety gold were found between 200 ft. and 300 ft. in this mine on the hanging-wall of the dyke. Several nuggets up to 4 or 5 oz. in weight were exhumed from these patches. The gold was mostly free from quartz, and was associated with spongy native copper, azurite, and malachite, limonite, and a greasy micaceous decomposition product of the dyke termed "mutton fat." This material is common in the vadose zone in many mines in dykes, and appears to be a mixture of potash and soda, mica, talc, limonite, kaolin, and free quartz.

Little Comet Mine, Wood's Point.—The dyke worked in this mine is of the narrow type—6 to 10 ft. in width. It is traversed by the usual flat floors of quartz, which in this case are intersected by nearly vertical veins. Rich patches of gold were obtained at and close to the intersections of these veins. One such mass of gold, aggregating in weight more than 80 oz., was discovered in 1913 at a depth of about 220 ft. It was associated with a little quartz and some limonite and malachite. Massive secondary pyrites filled in the interstices between the quartz crystals.

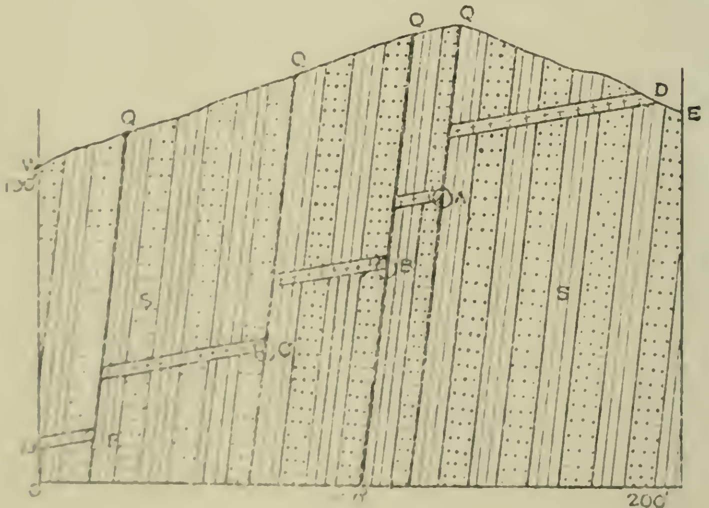

FIG. 9.

SKETCH SECTION OF THE HOME RULE MINE NEAR GAFFNEY'S CREEK.

Showing localization of pockets of gold—A, B, C, E; "Q" = quartz reefs; "D" = lamprophyre dyke; "S" = Silurian slates and sandstones.

Home Rule Mine, near Gaffney's Creek.—The dyke, a narrow one, averaging about 2 ft. in width, dips at an angle of about 20°

to the west, cutting across the strata, which dip here to the west at about 75°. Four step dip-slip faults, in which small laminated quartz-veins have formed, displace the dyke, as in the figure.

The fault-reefs and the veins in the dyke were relatively poor, averaging less than 5 dwt. per ton, but rich patches of gold occurred in the vicinity of the points A, B, C, and D in the figure. The richest values came from pocket " A," which averaged about 30 dwt. to the ton, while the ore from " E " averaged less than 8 dwt. per ton. The greater part of the gold in these patches occurred loose, and not in the quartz. It was associated with limonitized pyrite, native sulphur, and hydrated oxide of iron. The bulk of it was coarse, but some finely-divided flour gold was also present.

Alabama Mine, near Ten-Mile.—The Alabama reef is a narrow bedded laminated reef, normally less than 6 in. in width. At a depth of about 150 ft. from the surface the reef intersects and displaces for a distance of a few feet a lamprophyre dyke, which averages about 6 ft. in width. The Alabama reef at this point dips at an angle of about 80° to the west, and the dyke at between 50° and 60° to the west. At the intersection with the dyke the reef bulges to as much as 4 ft. in width, and rich pockets of gold were found in the quartz in this vicinity. The gold occurred in the form of strings and veinlets through the quartz, and was associated with much red hydrated oxide of iron.

The following tabulated yields from this mine illustrate well the enrichment between 140 ft. and 200 ft. :—

Depth in feet.	Tonnage crushed.	Yield.	
	tons	oz.	dwt.
0-50	27	72	0
80-90	90½	145	6
120	34½	56	3
140 and 150 ..	208	1172	0
200	279¾	1390	3¼
300	18	51	11

A 1 Mine, Gaffney's Creek.—That an important enrichment occurred in the ore-values in this mine between 100 ft. and 180 ft. from the surface is evident from the following yields, culled from the reports of the mining surveyors and registrars for the period 1862 to 1892:—

Depth in feet.	Ore Crushed	Yield
	tons.	oz
0-50	5652	7747
60-80	7991	10,962
100-130	10,567	20,511
150-180	3871	6626
200	1505	1267
250	120	48

Unfortunately, very little information is now obtainable as to the mode of occurrence of the gold in these upper levels. Mr. J. Friel, manager of the New Loch Fyne mine, Matlock, informed the writer that loose coarse gold, resembling smelted and alluvial gold, was found in vugs in the 60-ft. reef on ledges on the western wall of the dyke, and that films and leaves of gold free from quartz were not uncommon in joint-planes in the dyke from the 300-ft. level of the South A 1 mine.

Morning Star Mine, Wood's Point.—More than £1,000,000 worth of gold has been won from this mine within 400 ft. of the surface. At least 90 % of this gold was unearthed between 1862 and 1875. The early records are incomplete, but as far as they can be interpreted they indicate that the richest quartz came, not from the surface, but from depths between 180 ft. and 350 ft., and particularly about 200 ft., as will be seen from the following figures:—

Date	Company.	Ore Crushed	Yields	Depth.
		tons.		ft.
Aug., 1862	—	—	averaging 5 oz. to the ton ..	near surface
Feb., 1864	M'Dermott & Co.	36¾	1619 oz. 4 dwt.	184
April, 1864	Hope	—	4 oz. to the ton	200
June, 1864	Wood's Point Co.	161¾	2632 oz. 4 dwt.	190
June, 1864	Drysdale and Co.	500	7500 oz.	(?) 230
Sept., 1864	Wood's Point Co.	147	2026 oz. 10¼ dwt.	200
Sept., 1864	Drysdale and Co.	300	1500 oz.	(?) 230

The bulk of the gold won from the Morning Star Hill came from two reefs—the Age of Progress, on the west wall of the dyke, and Cherry's reef, on the east wall. Both reefs run out into the Silurian strata, and have proved payable for long distances along the dyke walls. According to Mr. O. A. L. Whitelaw (No. 57, p. 16), the Age of Progress reef was worked along the western wall for 1500 ft., and was poor from the centre of the dyke to the east wall; and Cherry's reef was proved payable for 1100 ft. along the eastern wall, and was poor on the western wall. More than one-third of the total gold won from the Morning Star Hill came from these reefs outside the dyke walls..

Unfortunately, few facts relevant to the mode of occurrence of the gold in these reefs have been preserved. The late Mr. Stacpoole, who was conversant with the early workings in the Morning Star dyke, informed the writer that the gold frequently occurred as strings and veins associated with limonite and "mutton fat," in friable vitreous quartz, and sometimes loose in vugs.

As now seen in the stopes off the Hope adit-level, the Age of Progress reef is, for the most part, vitreous, non-laminated, barren-looking quartz. It is very friable and much iron-stained in places, and is very free from sulphides. Cherry's reef,. in the same adit-level, is composed of vitreous quartz, vuggy in places, and much iron-stained. Sulphides are rare or absent, and the dyke near the wall is much decomposed in places.

Between the 300-ft. and 600-ft. levels the present company has intersected several reefs, but up to the present they have yielded little gold. They are, in general, laminated and well mineralized, and the surrounding dyke is hard and little decomposed. The bulk of the gold occurred intimately associated with arsenopyrite along laminations in the quartz and in certain leaders in black slates outside the east wall of the dyke.

It seems very probable, from the available evidence and from the experience of other mines in this belt, that the very rich gold won in the early days from the Morning Star dyke was largely, if not entirely, of secondary origin, and that it was concentrated by long-continued denudation and solution of the gold. The present workings are in the zone of primary values, and such rich yields as of yore cannot be expected. On the other hand, it would be fatuous to claim that the gold is confined to the upper zone of surface decomposition, as every atom of evidence is contrary to this idea.

3.—Black Gold.

Black gold is the miners' term for gold coated with black hydrated oxide of manganese.

Messrs. Selwyn and Ulrich (No. 41, p. 41), speaking of Victorian alluvial gold, say:—

"In some leads—for instance, at Guildford, Daisy Hill, &c.—portion of the gold is commonly coated with black manganese or brown iron ore—'black gold.'"

Such gold was not an uncommon feature in the pre-deep-lead sands and gravels at Ballarat and in the Loddon leads.

Much of the gold from Knowle's and the Georgia dykes at Enoch's Point from shallow depths was of this type. The coating is not always psilomelane, but is often earthy arsenopyrite.

A nugget of black gold, weighing approximately 2 lb. troy, was obtained from the Ball Room chamber in the Eldorado mine, near Gaffney's Creek. Black alluvial gold has also been found in Gaffney's Creek, near Hunt's mine, and near Store Point.

4.—Permanence in Depth.

Until within the last fifteen years prospecting in depth was not encouraged in this belt. The pernicious influence of the theory of Mr. H. A. Thompson (No. 49, p. 246), that the quartz floors in the dykes were filling cracks near the surface, and as such were not likely to penetrate to any great depth, was largely responsible for this state of affairs.

That the mineralization is deep-seated is clear from the evidence brought forward in this paper. Furthermore, conduits must have existed for the conveyance of the auriferous ascending solutions, and the field examination has shown that fault-fissures and orogenic and contraction joints have provided the necessary channels. The recognition of this deep-seated origin of the gold and the initiative displayed by certain companies, such as the A 1 and the Rose of Denmark, in sinking and developing their properties in depth, has acted as an incentive to other companies —*e.g.*, New Loch Fyne and the Morning Star—to prospect their ore-bodies at lower depths, with the result that the New Loch Fyne management has struck a reef, crushings from which of late have averaged about 1 oz. per ton.

The average tenor of the ore from between the 850-ft. and 1000-ft. levels in the A 1 mine has proved richer than any ore previously taken from this mine, with the exception of that obtained from the secondarily enriched zone between 100 and 180 ft. from the surface. Notwithstanding the fact that a considerable amount of mullock was crushed with the quartz, 48,961 tons of it yielded 47,398 ozs. of gold during the years 1913 to 1918 inclusive. Almost the whole of this ore came from between 800 and 1000 ft.

Again, the quartz from the Rose of Denmark mine was relatively poor, averaging about 7 dwt., from the surface down to the main adit-level, a depth of at least 500 ft. at the engine chamber. Below this level the ore became richer, and about 40,000 tons of quartz, averaging about 11 dwt. of gold per ton, were crushed between the main adit-level and No. 5 below it.

It seems reasonable to expect that many other mines in this belt will, if developed in depth, show the same general result.

However, secondary enrichment has had a marked effect on the auriferous values of many of the quartz reefs, and its bearing on the tenor of the ore in depth must not be overlooked. Mines like the Royal Standard, Morning Star, Eldorado, New Loch Fyne, Leichhardt, &c., are not likely to prove as rich in depth as near the surface, owing to the extensive secondary concentration of the gold in their upper zones.

5.—SUGGESTIONS FOR FUTURE MINING, &c.

The assets of this belt for mining purposes are a good climate, plenty of timber for fuel and timbering, and, normally, a sufficient supply of water. The writer is of the opinion that much more use could be made of the Goulburn River and its tributaries for the generation of electrical and other power, and also for sluicing those vast high-level and other gravel deposits that have been so little worked.

The disadvantages with which the mines in this belt have to contend are as follows:—A youthful topography; absence of railways; bad roads; and the concomitant inflated costs of mining machinery, stores and provisions, and the difficulty of getting skilled labour.

For future mining to be a success, sound business methods and scientific development will have to be employed. The policy of the past, of picking the eyes out of the mines and disbursing every penny in dividends without a thought for the morrow, must not be tolerated.

Furthermore, development of this belt will not be possible until the economics of the gold question have been solved and the policy of our Government towards gold-mining has been defined. At present whole-hearted judicious Government support seems to be the only means of saving the industry. The present policy of expending an amount of some £10,000 to £20,000 annually to encourage mining in the State is absolutely futile, and defeats its own object.

The possibility of the discovery of new goldfields in this belt seems a remote one. Nature has been kind to the prospector in removing the overburden of the reefs, and, although the topography is wild and juvenile, prospecting, on the whole, has been very thorough. All the more important reefs were discovered prior to 1870, and finds since then have, with few exceptions, yielded little gold.

The possibility of reefs which are barren or poor at the surface becoming payable or rich in depth owing to the complete solution of the gold from near the surface in descending waters must not be overlooked, and no mine can be condemned as a "dud" concern until it has been tested below the base of the zone of surface decomposition. Many mines in this belt have not been prospected in the primary sulphide zone, and consequently their worth or otherwise has not been proven. Further, many reefs have not been thoroughly explored and developed near the surface —*e.g.*, Unknown, Royal Standard, Eldorado, Little Comet, &c.

Although boring is not of much value for sampling reefs, it is useful in locating new ones, particularly in dyke formations. It is relatively cheap, and could be applied with justification in certain places in this belt—*e.g.*, Royal Standard mine, where considerably more than £50,000 worth of gold was won from within 100 ft. of the surface, and no reefs have been located at lower levels.

The tribute system should be encouraged. Numerous instances could be quoted of tributing parties locating new reefs and shoots of gold, which often have given new lease of life to abandoned and struggling mines.

It is a widely-accepted belief among miners in this belt that the vicinity of the walls of the dykes are the favourite places for finding gold. This theory is in keeping with the facts of the gold-occurrence in the vadose zone, and is readily explained, as the walls of the dykes have afforded the easiest channels for surface descending auriferous solutions, but caution should be exercised in applying the theory generally, as it has not been demonstrated that the gold-occurrence in the primary zone conforms to it.

The petrologist can be of some assistance to the miner in that he can determine whether any particular dyke is likely to be auriferous or not. The results of the present investigation indicate that payably-auriferous reefs are confined to dykes of dioritic and gabbroidal composition in this belt, and that the more acid and more basic ones are either non-auriferous or poorly so.

In conclusion, the following tried mines are regarded as the ones most worthy of further attention, viz.:—Unknown, All Nations, Star of the West, Gleeson's and Sailor Bill's, Royal Standard, and Eldorado. The Unknown mine was rich near the surface, averaging more than an ounce to the ton to a depth of 150 ft. Below this level it remains almost untested. Gold can be seen even now in specimens picked from the surface outcrop and shallow workings on the reef.

The All Nations, from which approximately 132,000 oz. of gold were unearthed, was a very promising reef near the surface, and at one time was regarded by the District Mining Surveyor as a better proposition than the Morning Star. No systematic work has been done to test it below a depth of 400 ft. from the surface.

6.—NOTES ON THE ORIGIN OF NUGGETS.

Accepting as a postulate that the nuggets found in the alluvial in Victoria were shed from quartz-veins—a belief the evidence in support of which is overwhelming—what, then, has been the cause of the aggregation of such large masses of gold in the veins? Current explanation invokes the aid of an indicator—a term somewhat loosely applied to thin bedded pyritic, chloritic, and carbonaceous seams, laminated iron-stained quartz-veins, narrow fissures or fractures, and "pug seams." Where these indicators intersect a more or less flat vein of quartz, nuggety gold is the rule.

In the only area in the region described in this paper from which many nuggets have been unearthed from the alluvial—namely, Enoch's Point—nuggets have been shown to occur in such a manner in certain dykes—*e.g.*, Knowle's and the Georgia—as to leave no doubt whatever as to their deposition from secondary surface-descending auriferous solutions at points where the descent of these waters has been impeded. Furthermore, the secondary origin of the May Moon dyke nuggets and those from Sutcliffe's and the Little Comet mines is undoubted.

It is believed that many, if not most, of the nuggets found in quartz reefs and alluvial deposits in Victoria have originated in a similar manner, and in the following pages evidence will be brought forward in support of this theory.

With the exception of the Ballarat East goldfield, the nuggets found in quartz reefs in Victoria have, in practically all cases, come from depths less than 400 ft. or 450 ft. from the surface. At Kingower, Wedderburn, Dunolly, Moliagul, Rheola, and Maryborough—fields notorious for the size and number of the alluvial nuggets—rich nuggety gold has been extracted from many of the quartz-veins within 300 ft. from the surface ; but below this depth payable reefs are exceptional, and nuggets are unknown.

Messrs. Selwyn and Ulrich (No. 41, p. 41), in dealing with the mode of occurrence of gold in Victoria, state that

"It is found by practical experience that the gold at and near the surface is coarser . . . than in depth, and, although exceptions are known, it is by most quartz miners acknowledged, so to speak, as a rule that the gold becomes finer and finer and more intimately mixed with the quartz and pyrites the deeper the reefs are worked."

At Ballarat East we have an exception to this rule, for nuggets have been won from depths as great as 1300 ft. from the surface. However, this field is intensely fractured and faulted, and such minerals as kaolin and radial marcasite, which are generally acknowledged to be formed by surface descending waters, were not uncommon in the reefs in certain mines—*e.g.*, North Woah Hawp—at depths as great as 1200 ft. A study of the paragenetic relations of the vein-minerals shows that in all cases the gold was the last mineral introduced into the reefs. Furthermore, the way the gold occurs deposited on the sulphide minerals sphalerite and galena, and less commonly pyrite and pyrrhotite, and filling fractures in friable quartz, suggests a secondary origin for it.

Professor Gregory (No. 18, p. 44) says :—

"Many facts suggest that most of the gold in the Ballarat East goldfields has reached its present position by the action of solutions descending from above,"

and gives evidence in support of this contention. The writer thinks the facts warrant the conclusion that the bulk of the gold of the Ballarat East field is of secondary origin, and that it was probably deposited from descending waters. The indicators apparently provided the necessary precipitants for the gold in solutions crossing them.

On certain other fields, as will be seen from the following examples, the indicators apparently were channels along which auriferous solutions circulated. At Wedderburn the indicator is usually a thin bedded iron-stained quartz-vein within beds of carbonaceous slate. In his report on this area (No. 56, p. 13), Mr. O. A. L. Whitelaw says:—

"I have not noticed one instance of an indicator producing rich pockets of gold where this metasomatic quartz is absent."

He, furthermore, claims that the gold-bearing solutions circulated along the fault-planes and in the indicators themselves, and quotes analyses showing that the indicators are always auriferous.

According to Mr. R. A. F. Murray (No. 36, p. 5), at Paddy's Gully, Rokewood Junction, a drive along a reef at between 20 and 30 ft. from the surface showed a narrow, soft, slaty band, sometimes ferruginous, sometimes soft and clayey, varying from brown or grey to nearly black in colour, in contact with the hanging wall of the reef. This band is claimed by Mr. Murray to be an indicator, and, according to him,

"An inch or two of the stone in contact with the slate band is of friable character, and in this lies the gold, in places stated to be in the form of an almost solid vein, in pieces up to several ounces in weight. The rest of the reef is of the character known as 'buck,' or stone of a hard, glassy, unpromising character."

This example, in the writer's opinion, is very significant of a secondary origin for the gold from descending waters.

According to Mr. W. Bradford (No. 6), the indicator in the Pyrenees goldfields is often a thin bedded ferruginous quartz-vein, which sometimes carries free gold.

At Moliagul and Rheola the indicators are sometimes thin ferruginous quartz-veins and fissures filled with soft clay or pug. Finely-divided "flour" gold is not uncommon in these indicators.

In other cases cross-veins and faults appear to have provided the conduits for the auriferous solutions, and the nuggety gold occurs in the vicinity of some pyritic or carbonaceous precipitant. At Maryborough, for instance, the indicator is usually a thin bedded, laminated quartz-vein within a bed of green or purple pyritic slate. According to Mr. A. M. Howitt (No. 24, p. 15), gold never occurs in the indicators. He says:—

"In some cases the gold shoot is at the junction of the cross-vein with the laminated quartz-vein in the indicator, but this happens only when secondary pyrites is disseminated in the laminated vein, as at Inkerman and Alma. In other cases, as at Waterloo, the rich gold shoot is just to one side of the laminated quartz-vein, and opposite a decomposed pyritic seam."

And further—

"In every case noted of enrichment along the indicator, pyrites was present under one or other of these conditions."

The cross-veins were usually narrow and very ferruginous. According to Mr. Howitt, round, shotty gold, generally partly coated with oxide of iron and in some cases resembling water-worn gold, is found in some of these veins at or close to their intersections with the indicators.

From within a few yards of the outcrop of the Matrix reef, near Rheola, nuggets of 810 oz., 805 oz., and 782 oz., and one of 59 lb. weight, were exhumed. Several patches of nuggety gold have been obtained from the reef itself. Mr. H. S. Whitelaw (No. 54, p. 32) claims that

"The gold patches occur only where a thin cross-vein of quartz, 2 in. to 12 in. thick, intersects a lead-coloured slate in the immediate vicinity of a fault."

From one of these pockets, at a depth of less than 100 ft. from the surface, 258 oz. of gold were taken out of a space of 1 cub. ft. The quartz carrying the gold is highly ferruginous.

The structure of many alluvial nuggets lends support to the theory that they were deposited from surface-descending auriferous waters.

Several Victorian alluvial nuggets examined by Prof. A. Liversidge (No. 32, p. 260) enclosed considerable amounts of ferric-hydroxide, although in many cases they were apparently not porous, and the hydroxide of iron was not visible at the surface. The Latrobe nugget, 40 oz. in weight, from the M'Ivor goldfield, is a mass of reticulating crystals of gold. The writer believes that this nugget is now preserved in the Natural History Museum, in London. Flat nuggets with approximately parallel sides were not uncommon in the alluvial. Nuggets of this type of secondary origin have been described in the present paper from the Georgia mine, near Enoch's Point. Professor A. Liversidge also described a flat nugget from Gippsland, which, according to him, appears to have been formed in a narrow fissure.

Again, the nuggety gold found in our quartz reefs is invariably of good quality, and rarely is of less fineness than 950. The indicator gold of the Ballarat East goldfield was notorious for its purity—999.5, according to Professor Gregory (No. 18, p. 44)—and that from Wedderburn, Moliagul, and Maryborough was of greater average fineness than 950. At the last-named place the indicator reef gold was always purer than the normal reef gold not associated with indicators. Furthermore, Dr. Don's comprehensive analyses of the gold obtained near the surface and from depth at Ballarat and Walhalla, in Victoria, and from other Australasian goldfields, indicate that

" On the whole the average fineness of the gold in the vadose zone is appreciably greater than in the deeper circulation in the same district " (No. 10, pp. 607, 608).

This refining of the gold in the vadose zone, of course, may have taken place after its deposition, but, considered in conjunction with the mode of occurrence, mineral associations, and the character of the gold, it seems more probable that it was deposited in the refined form.

In conclusion, the writer is of the opinion that the abovementioned data strongly support the theory that most nuggets in reefs, and consequently those found in the alluvial in Victoria, have been deposited from secondary descending vadose solutions.

PART IV.—GENERAL SUMMARY, &c.

1.—General Summary.

Highly folded marine sediments of Silurian and Ordovician age form the bed-rocks of the Walhalla–Wood's Point belt. Silurian beds cover the whole of the central geosynclinal area of the belt, while the Ordovician strata appear at the flanks in the cores of domed geanticlinal inliers.

The uppermost beds of the Silurian—the Walhalla beds—are of shallow water marine or estuarine origin, and consist lithologically of grits and conglomerates, with intercalated coral and crinoidal limestones, feldspathic sandstones, and thin bedded black shales. Their fossil contents show that their stratigraphic position is very high in the Silurian series.

The Panenka and Monograptus beds are rich in fossils, and appear to be of deeper water origin. The Store Point–Mount Useful beds are, in the absence of fossil remains, provisionally included with the Silurian beds.

The Ordovician beds consist for the most part of highly-cleaved black slates rich in graptolite remains.

The main folding of these sediments occurred in Devonian (?) times, and was accompanied by extensive faulting and vulcanicity and the formation of the auriferous quartz-veins. The average trend of the sediments is N.N.W. They bend round the Baw-Baw granodiorite massif, the intrusion of which has probably caused this curvature.

As a concomitant of the folding and faulting came the intrusion of the dyke rocks of this belt. These dykes follow closely the strike of the sediments, and are most abundant in the central geosynclinal area. Normally, the dykes are narrow, but occasionally they expand into elliptical intrusions as much as 300 ft. wide. They form a petrographic province in which the following rock-types are represented :—Granophyres, aplites, quartz feldspar porphyries, diorite porphyrites, lamprophyres, gabbro porphyrites, basalt, hornblende-pyroxene rocks, hornblendites, and peridotite. That these dykes are consanguineous is proved by the remarkable similarity in their petrological characters, structural features, and metasomatic alteration. Their age is apparently Devonian, as they are overlain by the Lower Carboniferous beds near Mansfield, and are intrusive into the uppermost beds of the Silurian.

The petrology of these dyke rocks has been discussed at some length—firstly, because some of them are new types to Victoria; secondly, because no detailed description of them has been attempted previously; and thirdly, because the nature of the metasomatic alteration undergone by them is so interesting and economically important.

Not one specimen collected in the field was free from metasomatic alteration. The following types of alteration are recognizable:—

1. Regional alteration, before the intrusions had cooled sufficiently to fracture, by mineralizers released from the magma. There appear to be two stages in this alteration—

    (*a*) A late magmatic stage characterized by the development of interstitial quartz albite, orthoclase, and micropegmatite. The actinolitic and tremolitic outgrowths to the hornblende crystals are probably formed at this time.

    (*b*) Propylitization characterized by the formation of abundant chlorite and leucoxene, and some massive carbonate, pyrite, and pyrrhotite and occasional epidote and zoisite.

2. Hydrothermal alteration of the wall-rocks adjoining the veins. The effect of the vein-solutions on the wall-rocks has been intensely destructive. All the minerals of the propylitic *facies*, with the exception of apatite and some of the quartz, have succumbed to the action of the vein-solutions, and have been replaced by ubiquitous dusty carbonates, flakes of sericite, and some albite, pyrite, and leucoxene. Chemically, the percentages of CO_2 and K_2O have been markedly increased and Na_2O and H_2O greatly reduced, and SiO_2, Al_2O_3, TiO_2, and FeO have been partially leached.

Many of the reefs within the narrow dykes appear to be filling contraction joints. In the dyke expansions the parallelism of the reefs with the joint-systems of the dykes and their prismatic arrangement suggest that the original jointing was determined by the contraction of the dykes during cooling. Movement has occurred along these joint-planes in many instances prior to the introduction of the quartz—*e.g.*, in the Morning Star and New Loch Fyne dykes.

On the other hand, many reefs within and associated with dykes occur in faults which are quite independent of contraction jointing.

Evidence is presented to show that some reefs have been enlarged by replacement of the wall-rock surrounding cracks or joints, and that in other cases they are simply fissure-fillings. A combination of replacement and deposition from solution in fissures is usual in most reefs.

The various theories usually propounded to explain the genesis of the gold in the quartz-veins have been examined, and the only one that harmonizes with the facts is the theory that the gold came from magmatic sources.

The lean copper ores in certain basic and ultra-basic rocks were probably introduced during the propylitic phase of alteration.

Arsenopyrite, bournonite, pyrite, sphalerite, tetrahedrite, and galena are the most prevalent sulphide minerals in the veins. Quartz and carbonates are the usual gangue minerals, but albite and sericite are sometimes present. Quartz, carbonates, albite, pyrite, sphalerite, galena, and sometimes arsenopyrite, antedate the deposition of the gold; the latter mineral is often intimately admixed with bournonite and tetrahedrite, and sometimes with arsenopyrite.

Structural features are believed to be far more important than stratigraphical zones in causing the localization of the gold. Payably auriferous reefs are found in or associated only with dykes of dioritic and gabbroidal composition.

The main deposition of primary gold appears to have been determined by precipitation of the gold in the ascending auriferous solutions by the previously-formed sulphide minerals—pyrite, sphalerite, galena, and arsenopyrite—and by carbonaceous and other rock-residues and occasionally by the vein carbonates.

Secondary processes — denudation, gravity, solution, and precipitation—have re-concentrated the primary gold, forming important shoots and pockets of gold within the vadose zone.

Many mines in this belt were very rich near the surface, but failed to maintain their values in depth. Such enrichment is believed to be due to the mechanical concentration in situ of the gold released from the former upward extensions of the reefs.

In numerous other instances marked enrichment occurred in the auriferous values within and near the base of the vadose zone. The mode of occurrence and the character of the gold from the enriched shoots and pockets in the lower part of the vadose zone show conclusively that it was deposited from descending solutions.

The walls of the dykes have often afforded the readiest conduits for these waters, and much of the gold has been deposited at points where structural features—*e.g.*, ledges, faults, cross-veins, &c.—have checked their descent.

In several mines nuggets of gold have been found on the dyke walls in such a manner as to leave no doubt whatever as to their origin from surface descending auriferous waters. It is contended that most gold nuggets in Victoria have been formed in a similar manner, and evidence is adduced in support of this theory.

Although secondary processes have caused considerable enrichment in the vadose zone, all the available evidence supports the belief that the gold values persist in depth. Mines like the Morning Star, New Loch Fyne, Royal Standard, and Eldorado are not likely to prove as rich in depth as near the surface, but there is no justification for the theory that the reefs in these veins will be unpayable within the primary zone.

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EXPLANATION OF PLATE I. (MAP).

Geological and Locality Map of the Walhalla-Wood's Point auriferous belt, constructed mainly from the survey maps of Messrs. W. Baragwanath and O. A. L. Whitelaw. The Upper Ordovician beds near Enoch's Point are not shown. The map shows clearly the localisation of the dykes and chief mines between the eastern and western basal grits of the Walhalla beds of Upper Silurian age.

EXPLANATION OF PLATES II. TO VII. (MICROPHOTOGRAPHS).

FIG. 1.—Aplite vein in Eureka dyke, near Walhalla, × 13 polarized light, showing stunted prisms of albite in a quartz base, laths of biotite, black needles of ilmenite, and speckled aggregates of sericite after feldspar.

FIG. 2.—Granophyre, Alabama dyke, near Matlock, × 20 polarized light, showing fine intergrowth of quartz and feldspar surrounding a large plagioclase crystal.

FIG. 3.—Sericitized quartz feldspar porphyry, Brohan's Reef, near Aberfeldy, × 15 polarized light, showing a rounded phenocryst of quartz, an irregular-shaped sericitized phenocryst of feldspar, and a large black crystal of pyrite having a fringe of secondary quartz.

FIG. 4.—Diorite porphyrite, Hope adit level, Morning Star dyke, showing phenocrysts of hornblende, including ilmenite, flakes of biotite, prisms of altered feldspar, and a micrographic intergrowth of quartz and feldspar.

FIG. 5.—Specimen No. 229, gabbro porphyrite, Coronation mine, Tubal Cain dyke, × 6 O.L., showing phenocrysts of augite, biotite, and plagioclase and black grains of ilmenite.

FIG. 6.—Specimen No. 214, porphyritic basalt, lower adit level, Coronation mine, Tubal Cain dyke, × 6 O.L., showing porphyritic phenocrysts of titaniferous augite veined by chlorite, in a fine-grained ground-mass.

FIG. 7.—Specimen No. 178, hornblende pyroxene dyke rock (perknite), 1 mile east of Toombon, × 16 O.L., showing fibrous actinolitic outgrowths to hornblende and inclusions of colourless monoclinic augite.

FIG. 8.—Hornblende pyroxene rock (perknite), Kelly's dyke, near Walhalla, × 16 O.L., showing micropœcilitic inclusions of colourless augite in hornblende.

FIG. 9.—Hornblende peridotite, near Aberfeldy, × 16 O.L., showing concentric and internal alteration of olivine.

FIG. 10.—Granophyre, Alabama dyke, near Matlock, showing a pseudomorph of chlorite and carbonate after an idiomorphic hornblende crystal. Leucoxene (black) has been partly concentrated towards the margin of the hornblende.

FIG. 11.—New Loch Fyne dyke, No. 5 adit level, north-west edge, × 27 O.L., showing the veining and replacing of a hornblende crystal by chlorite and carbonates.

Photos by the author unless otherwise indicated.

Fig. 12.—New Loch Fyne dyke, north-west edge of intrusion, No. 5 adit level, × 23 polarized light, showing the veining and replacing of a feldspar phenocryst by chlorite (pennine) along parallel lines. The black hexagonal inclusion is apatite.

Fig. 13.—Specimen No. 99, granophyre, Alabama dyke, near Matlock, × 15 O.L., showing radiating and stellate epidote and zoisite.

Fig. 14.—Intensely altered (carbonated) basic New Loch Fyne dyke, No. 5 adit level, × 17 O.L., showing "sagenitic" webs of rutile after biotite. Photo. by G. Sweeting, Esq.

Fig. 15.—Vein-altered lamprophyre dyke, Kelly's Hill mine, near Matlock, × 18 O.L., showing an epimorph of pyrite (black) on a crystal of leucoxene which replaces ilmenite.

Fig. 16.—Hydrothermally-altered Rose of Denmark dyke (hornblende lamprophyre), near a quartz-vein, × 15 O.L., showing idiomorphic crystals of pyrite and arsenopyrite in the sericitized and carbonated rock. A veinlet of quartz intersects a pyrite crystal.

Fig. 17.—Specimen No. 223, quartz-epidote-carbonate vein in basalt, Coronation mine, Tubal Cain dyke, × 16 O.L.

Fig. 18.—Copper-bearing New Loch Fyne dyke, No. 5 adit level, × 25 O.L., showing corrosion of biotite by chalcopyrite. The ring of light-coloured mineral between the chalcopyrite and biotite is carbonate.

Fig. 19.—Specimen No. J11*a*, auriferous quartz, No. 9 intermediate level, A 1 mine, × 15 O.L., showing the replacement-origin of the quartz. Skeletons of slate and sandstone are seen almost entirely replaced by granular quartz and dusty and granular pyrite.

Fig. 20.—Specimen No. J10, quartz-vein from stopes above No. 6 level, Rose of Denmark mine, × 19, crossed nicols, showing pellucid crystals of albite associated with quartz and ankerite.

Fig. 21.—Gold in ankerite, stopes above 220-ft. level, Little Comet mine, × 19 O.L., showing gold (black) encrusting and veining the ankerite.

Fig 22.—Auriferous quartz from No. 8 level, A 1 mine, × 17 reflected light, showing the intimate association of the light-coloured gold ("G") and the black bournonite ("B") and their subsequent origin to the idiomorphic quartz-crystals on which they are moulded.

Fig. 23.—Auriferous quartz, 850-ft. level, A 1 mine, × 9 reflected light, showing the relationship between sphalerite ("S") and bournonite ("B"). Photo. by H. Smith, Royal School of Mines, London.

Fig. 24.—Specimen No. 11*a*, No. 9 intermediate level, A 1 mine, × 17 O.L., showing idiomorphic quartz-crystals included in bournonite (black). A little gold is admixed with the bournonite.

Photos by the author unless otherwise indicated.

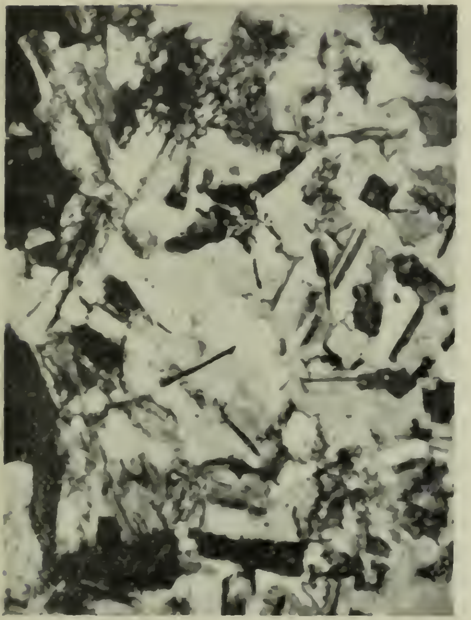
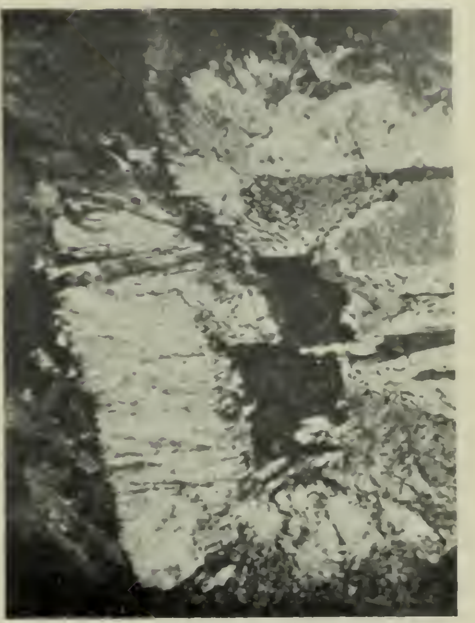


Fig. 1.



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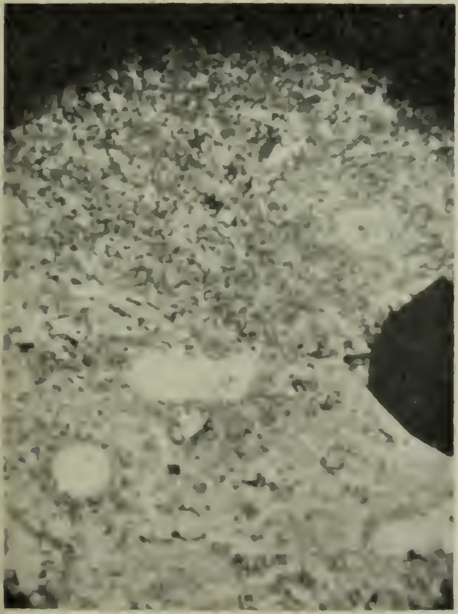

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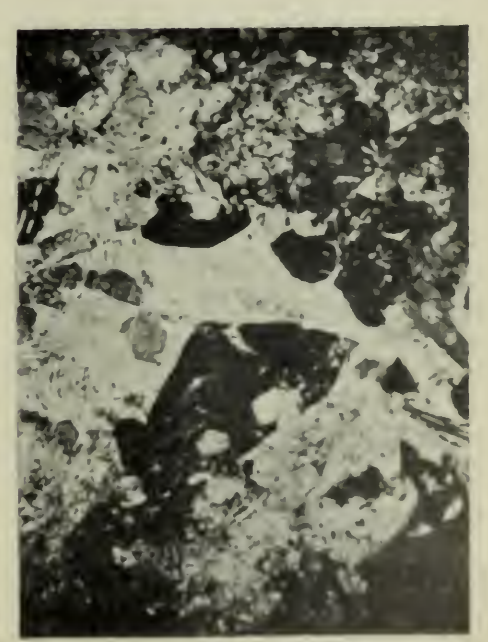

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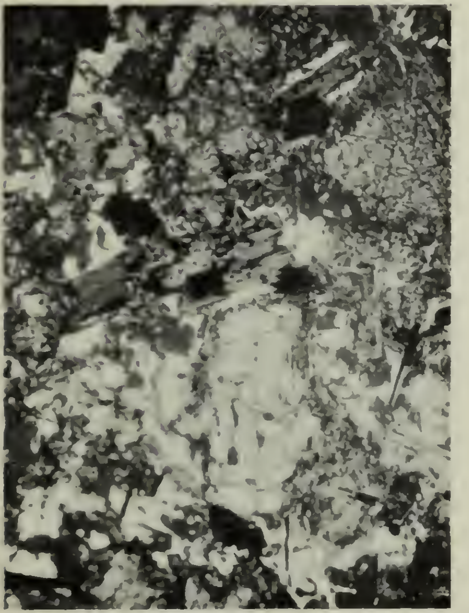

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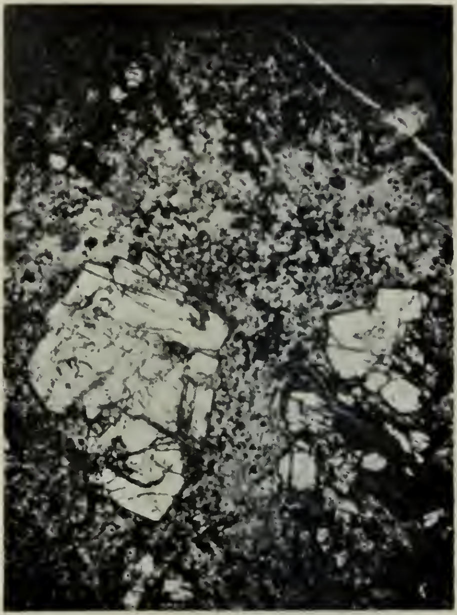

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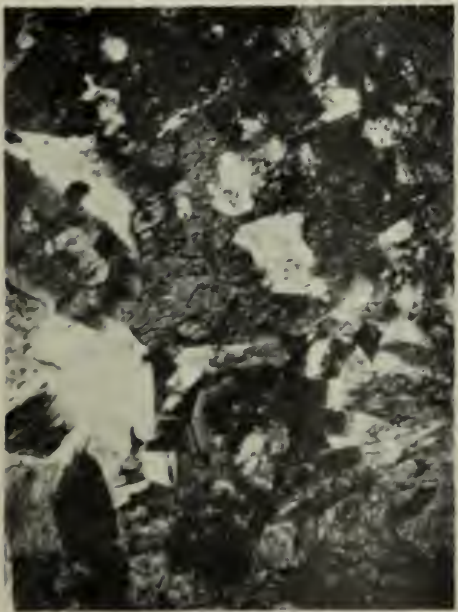

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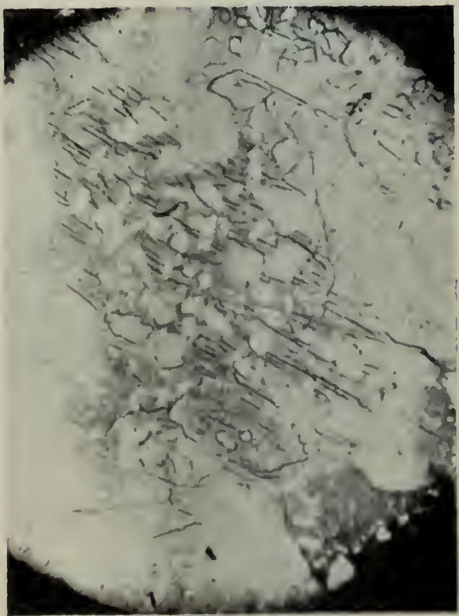

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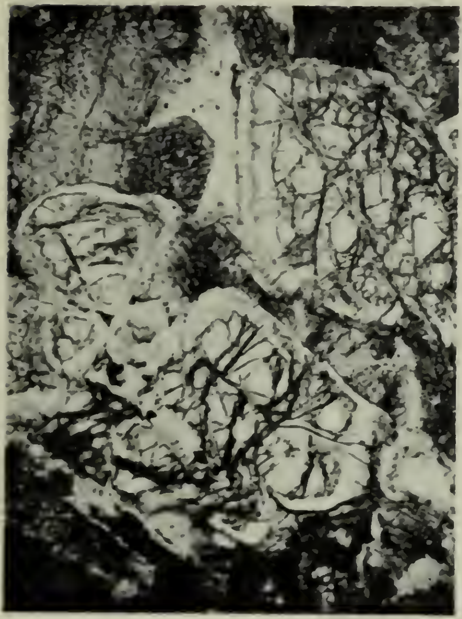

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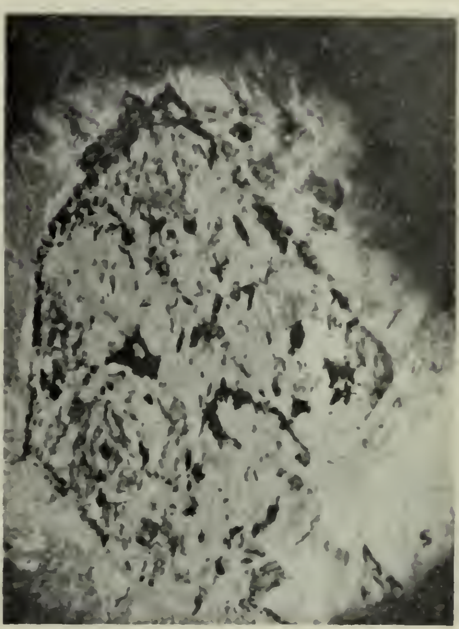

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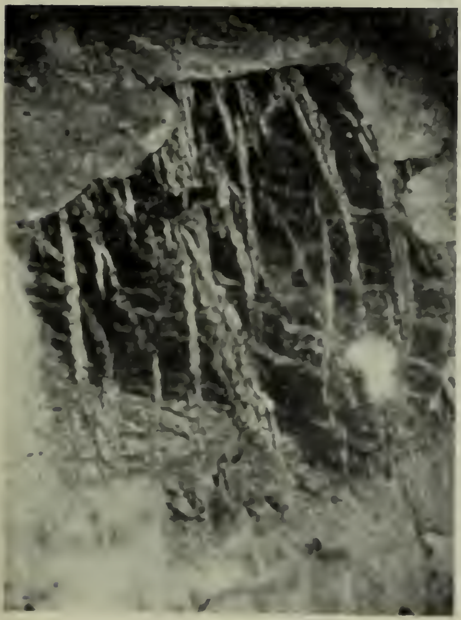

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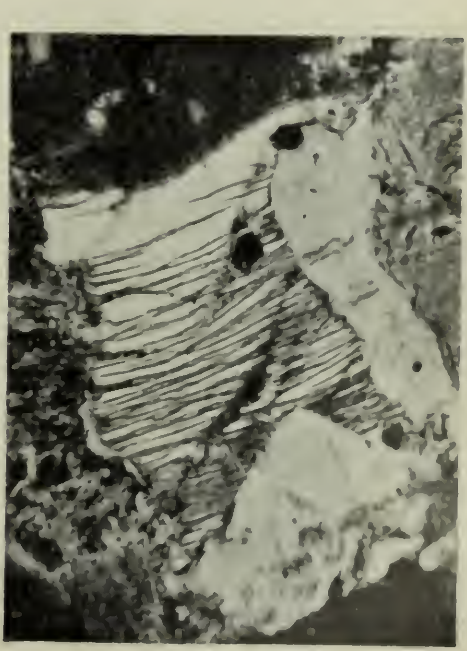

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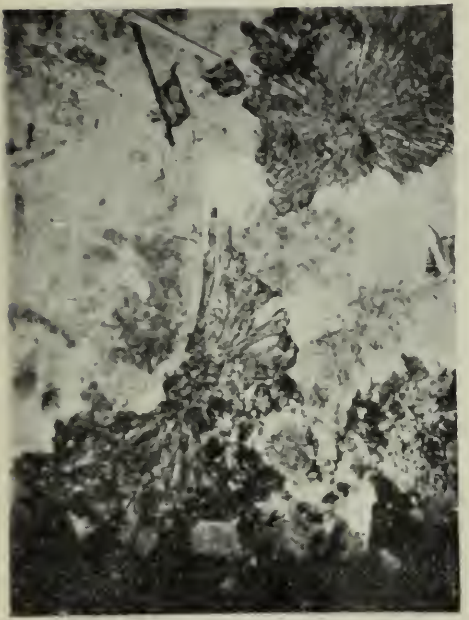

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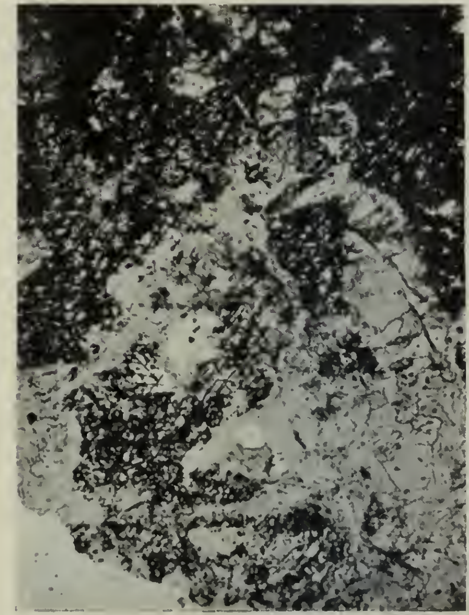

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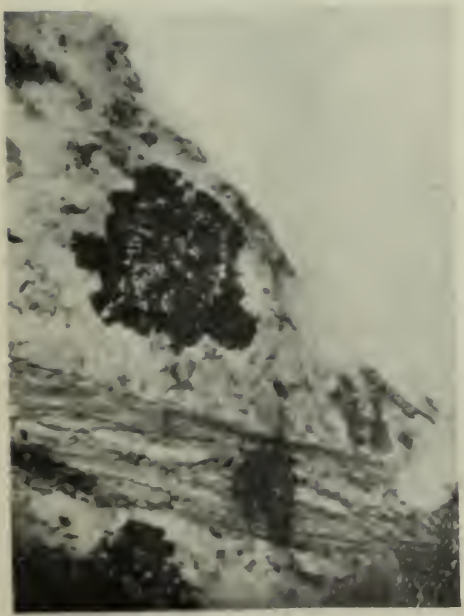

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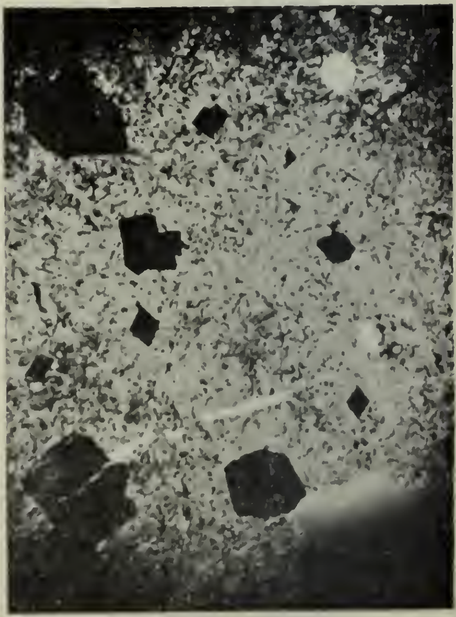

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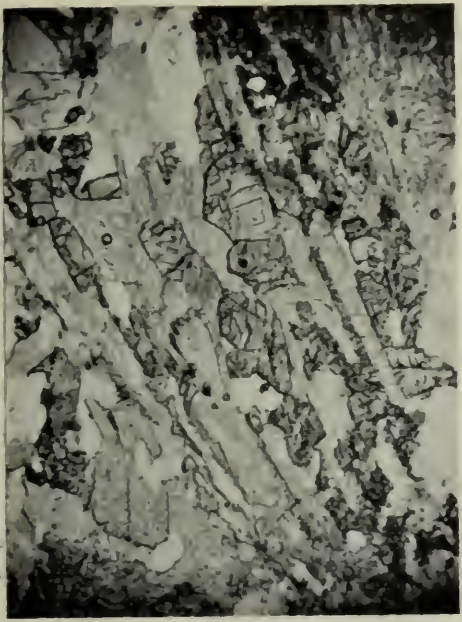

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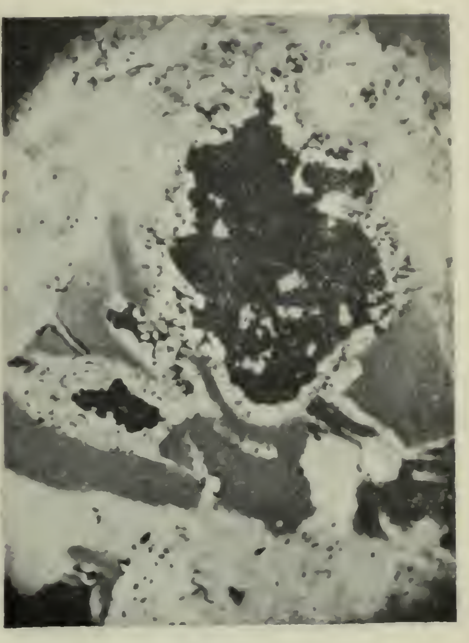

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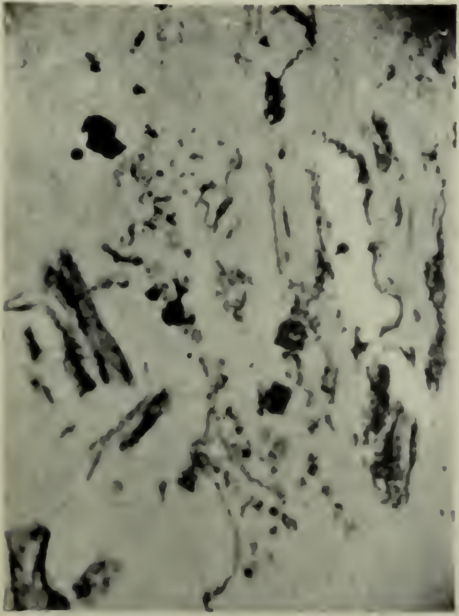

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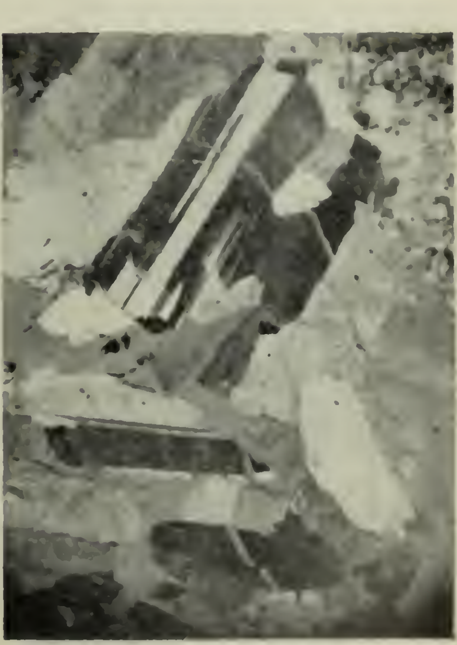

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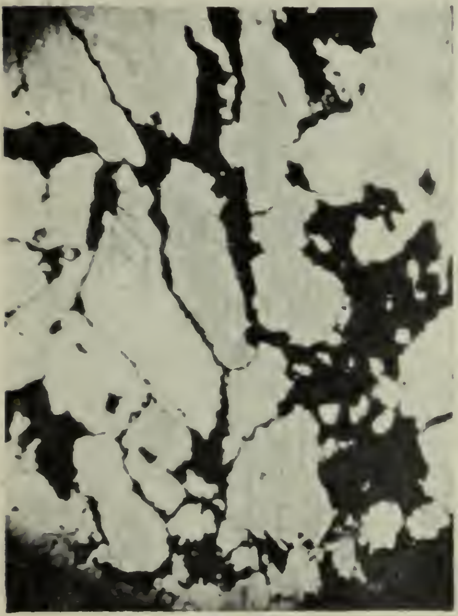

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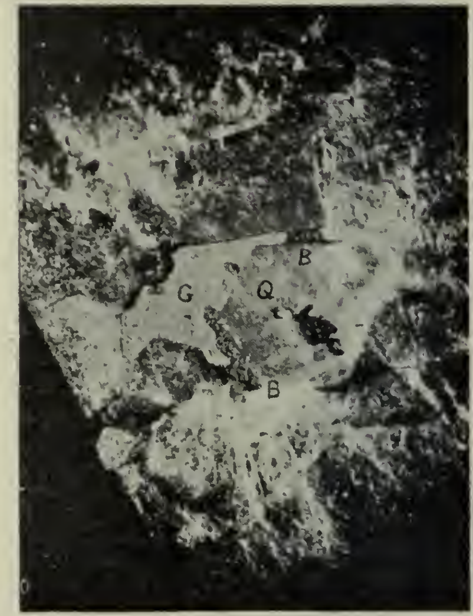

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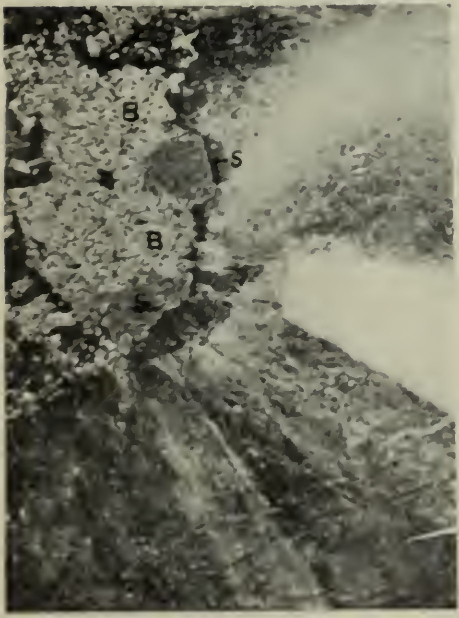

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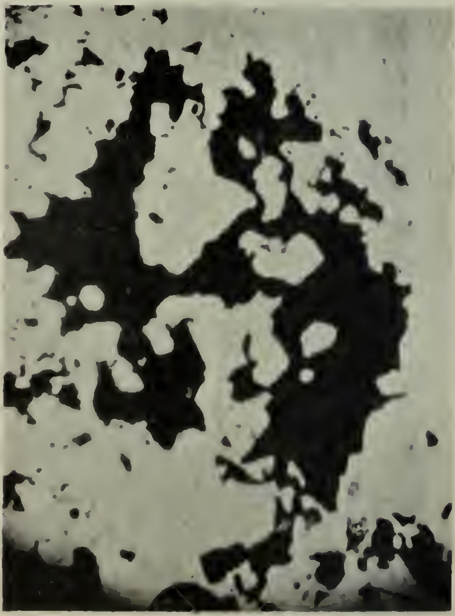

FIG. 24.

Papers and Discussions.

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PAPERS—

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TREATMENT OF WOLFRAM, BISMUTH, AND MOLYBDENITE ORES AT BURMA QUEENSLAND CORPORATION MILL, WOLFRAM, N.Q.

BY W. H. BOWATER.

THE old mill erected by the Irvinebank Company consisted of 10 heads of stamps (850 lb.), rock-breaker, Hartz jig, two Krupp tables, two Luhrig vanners, three sand-pumps, one mixer, six flotation vessels, and the necessary settlers. Power was supplied by a small colonial-type boiler and 10-in. x 15-in. Tangye engine. The ore was carted from the mines to the mill and hand-fed into the rock-breaker, and the broken product elevated into the battery bins and fed into the stamps, the pulp from the stamps passing to a classifier, the spigot to jig, tables, and vanners, the overflow from the classifier passing to settlers. After the removal of bismuth-wolfram concentrates, the pulp was pumped to the molybdenite flotation plant and the molybdenite recovered by flotation.

A commencement was made with the erection of the first unit (20 heads) of the new mill in August, 1917, and milling and concentrating commenced in February, 1919.

[This paper is separately bound, and may be, if so desired, detached complete from this number.]

ORE.

The ore is essentially quartz, the richer values occurring in "lumps" and "patches" in this quartz. Between the quartz and the granite there is a "transition" zone, through which the molybdenite is more evenly distributed. The chief minerals are molybdenite, wolfram, metallic bismuth, bismuth sulphide, bismuth carbonate, and, rarely, a little scheelite. The wolfram is of a very friable nature, and, as the quartz gangue is the medium of crushing the molybdenite, a happy medium has to be struck in the size of battery screens, care being taken to slime the wolfram as little as possible and to crush the molybdenite as much as possible.

MILL.

The ore from the company's various mines is delivered by the aerial ropeway into the off-loading bin (see fig. 1), passing from this bin over No. 1 grizzly with 2-in. openings. The oversize from No. 1 grizzly passes to No. 1 jaw crusher, set to break at 2.5 in., and thence to No. 2 grizzly with 1.5 in. openings. The oversize from No. 2 grizzly passes to No. 2 jaw crusher, set to break at 1.5 in., then joins up with the fines from No. 1 grizzly and No. 2 grizzly, the whole then passing to the intermediate bin.

From the intermediate bin the ore is trammed to the battery bins, side-tipping trucks of one-ton capacity being used. The ore is distributed as required for each 5 heads of stamps.

At present the first unit of 20 heads of stamps is in commission, arranged in groups of 5 to each box. From the battery bins the ore is automatically fed through Challenge ore-feeders to the stamper boxes. Stamps are of 1250 lb., run at 100 drops per min., with from 6i-n. to 7-in. drop. The depth of overflow is approximately 10 in. Woven wire screens are used with aperture of 1/10 in. to 1/12 in., the latter for ore richer in molybdenite. The stamp duty varies from 5.5 to 5.8 tons per head per 24 hours.

The mortar boxes are set on concrete foundations with a $\frac{5}{8}$-in. rubber sheet between the box and concrete. This is found to be very effective, and no trouble is experienced with mortar boxes.

The pulp, passing from the stamper boxes. is automatically sampled before passing to hydraulic classifiers (No. 1 group), one

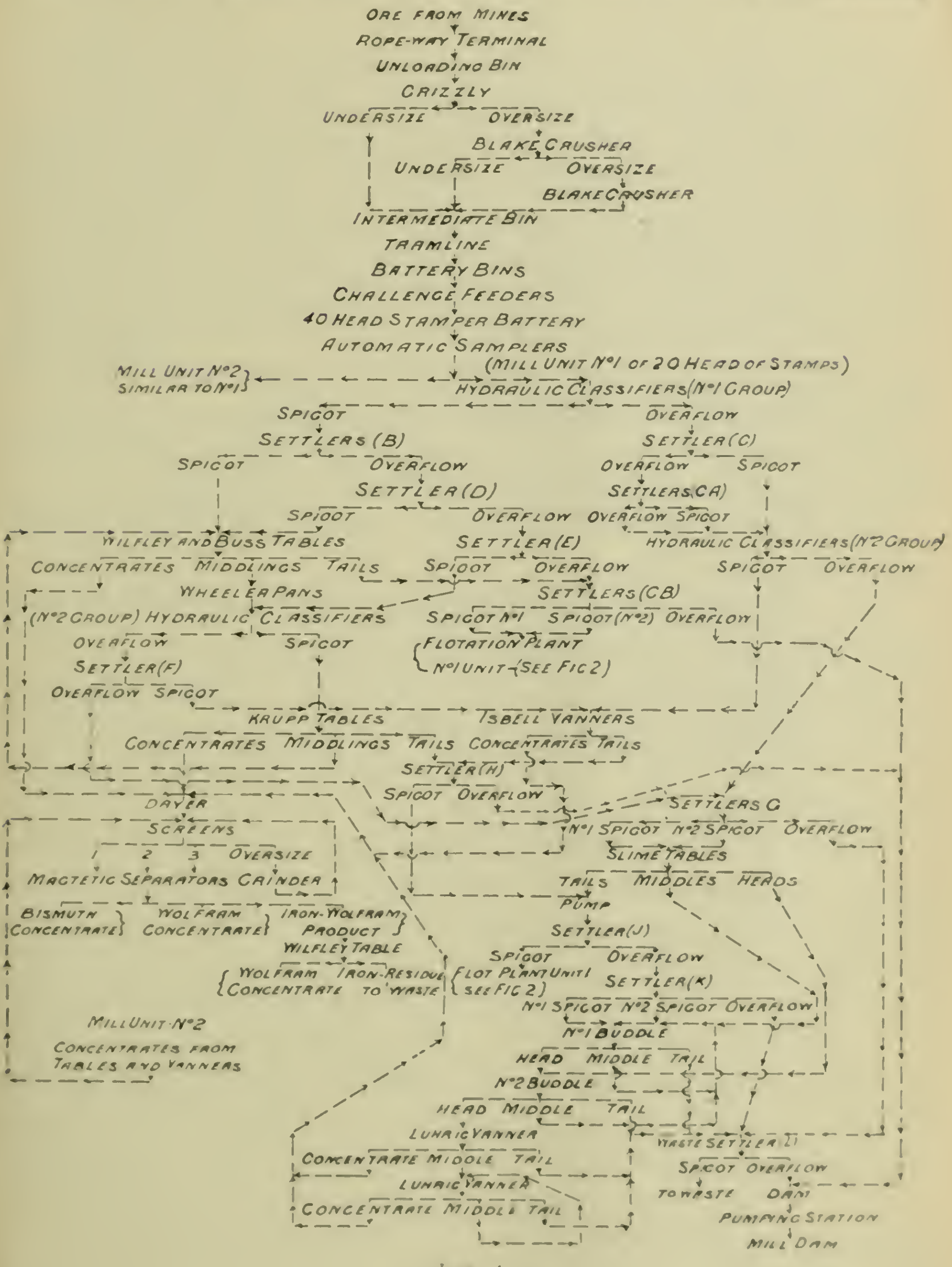

FIG. 1.

FLOW SHEET.

BURMA QUEENSLAND CORPORATION'S MILL, WOLFRAM, NORTH QUEENSLAND.

classifier for each 5 heads of stamps. The spigot (¾ in. dia.) from each classifier passes to its settler (B), the overflow from each classifier joining up and passing to settler (C), the overflow of settler (C) being divided and passing to two settlers (CA).

The spigot (½ in. dia.) from each settler (B) passes to Wilfley and Buss tables, one table to each settler. The overflow from settlers (B) joins up and passes to a large settler (D), the spigot (⅝ in. dia.) of which passes to a Wilfley table. The overflow of settler (D) passes to a still larger settler (E), the spigot (⅝ in. dia.) of which is sent to classifier No. 2 group (see later), the overflow being sent to the tailings launder of the group of Wilfley and Buss tables, assisting to flush out this launder.

Three products are made on the concentrating tables—viz., bismuth–wolfram concentrates, middlings, and tailings.

The bismuth–wolfram concentrates assay 30 % to 45 % WO_3 and 5 % to 7 % Bi.

The middlings assay approximately 8 % to 10 % WO_3 and 5 % MoS_2, and contain a fair percentage of pyrites.

The tailings contain .1 % to .13 % WO_3. The percentage of MoS_2 varying, depending on the degree of fineness of stamping.

Concentrates.—These are sent to the drying and magnetic separation room (see later).

Middlings.—These pass to Wheeler pans, thence to hydraulic classifiers (No. 2 group). The spigot of these classifiers (½ in. dia.) pass to Krupp tables, producing bismuth–wolfram concentrates, middlings, and tailings. The bismuth–wolfram concentrates assay 25 % to 40 % WO_3 and 3 % to 5 % Bi, and are sent to the drying and magnetic separation room. The middlings from the Krupp tables are elevated back to the Wilfley table dealing with the spigot from settler (D). The overflow from each classifier joins up and passes to a settler (F). The spigot (½ in. dia.) of this settler passes to an Isbel vanner, producing bismuth–wolfram concentrates and tailings. The concentrates, containing 15 % to 25 % WO_3 and 3 % to 4 % Bi, are sent to the drying and magnetic separation room. The overflow passes to two settlers (G). The spigot and overflow of settlers (C and CA) also pass to two classifiers (No. 2 group), the spigots (½ in. dia.) of which join up and pass to an Isbel vanner, the overflow of the classifiers passing to settlers (G).

Tailings from Wilfley and Buss Tables.—These are passed to two settlers (CB), the spigots of which join up and are sent to the molybdenite flotation plant (No. 1 sub-unit), the overflow being pumped back to the mill reservoir.

Tailings from Krupp and Vanner Tables.—These are passed to a settler (H), the spigot (¾ in. dia.) of which is passed to the molybdenite flotation plant (No. 2 sub-unit), the overflow going to the creek dam.

Slimes.—The spigot of settler (G) is run to slime frames, producing a low-grade concentrate and tailings, the overflow going to the waste settler (L). The tailings join up with the spigot of settler (H) and pass to the molybdenite flotation plant (No. 2 sub-unit).

The spigot of settler (K) (see later), together with No. 2 head of the slime frame concentrates, is sent to a buddle (No. 1), the overflow going to waste. No. 1 head of this buddle, together with No. 1 head of the slime frame concentrates, is re-treated in No. 2 buddle. No. 2 head of No. 1 buddle is re-treated in No. 1 buddle, and No. 3 head is sent to waste. No. 1 head of No. 2 buddle is treated on a Luhrig vanner table, producing bismuth–wolfram concentrates, middlings, and tailings.

The concentrates are sent to the drying and magnetic separation room. The middlings are returned to the vanners, and the tailings sent to waste. No. 2 head of No. 2 buddle is re-treated in No. 1 buddle, and No. 3 head sent to waste.

Treatment of Bismuth–Wolfram Concentrates (see fig. 1).—The bismuth–wolfram concentrates are dried, sampled, weighed, and assayed. They are then sized into three grades (through 30-mesh, through 16-mesh, and through 12-mesh) and magnetically separated. Any oversize is crushed and re-sized.

Two magnetic separators of the Dalbouze bracket type are at present at work. Current used is 110 volts at 11 amps. The product from the separators consists of clean wolfram concentrates and a bismuth concentrate containing the bismuth, together with a little wolfram. A small amount of iron residue is also obtained, which contains a small percentage of wolfram. These residues are dressed on a Wilfley table, producing a fairly high-grade wolfram concentrate, which is shipped with the concentrate above.

The wolfram and bismuth concentrates from the separators are then ready for shipment.

Molybdenite Flotation Plant (see fig. 2).

This has a complete unit for each mill unit. Each unit consists of two sub-units, No. 1 dealing with the tailings from the Wilfley and Buss tables and No. 2 dealing with the tailings from Krupp tables, Isbel vanners, and slime frames.

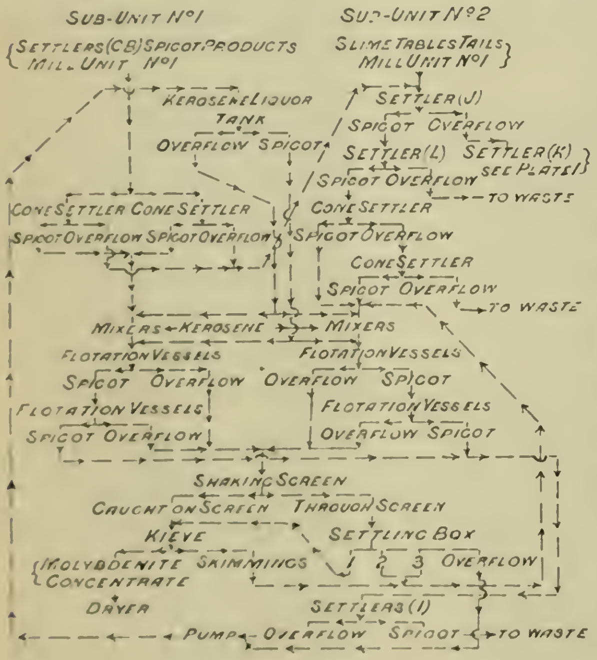

Fig. 2.

Molybdenite Flotation Unit No. 1.
Burma Queensland Corporation Mill, Wolfram, North Queensland.

No. 1 Sub-unit.—The spigots from settlers (CB) are passed to two settlers of the cone type in order to be de-watered as much as possible. The de-watered pulp is passed to a mixer, the stirring blades revolving 175 r.p.m., the necessary oil required being added in this mixer. From the mixer the pulp is fed to distributors on No. 1 set of four flotation vessels. The flotation vessel is of the cone type, with an approximate diameter of 4 ft. 9 in. and depth 3 ft. 3 in. The distributor occupies 1 ft. 11 in. of the centre of the vessel, leaving 1 ft. 5 in. of the outer diameter of the vessel as "flotation area."

The spigots of No. 1 set of flotation vessels pass to distributors on No. 2 set, the concentrates passing to a de-waterer. The spigots of No. 2 set are sent to two large settlers (I), the liquor overflowing to the storage reservoir, and the "tails" passing to waste, the various "overflows" joining up at this point and providing the necessary flushing water. The concentrates from No. 2 set of flotation vessels join up with those produced from No. 1 set and pass to the "de-waterer."

The overflow from the two cone settlers is passed to a large settler (J), the spigot (½ in. dia.) of which is sent to No. 2 sub-unit, the overflow passing to a still larger settler (K) (see above). This precaution is taken in case of the overflowing of the two cone settlers, in addition to obtaining a better settlement of the fine material.

No. 2 Sub-unit.—The tailings from the Krupp tables, Isbel vanners, slime frames, and spigot of settler (J) are sent to a large settler (L). The spigot (¾ in. dia.) is passed to two cone settlers, the overflow going to waste.

The de-watered pulp from the cone settlers is then dealt with as in No. 1 sub-unit, the feed from the mixer passing to distributors on No. 1 set of three flotation vessels and concentrates to the de-waterer. The spigot of No. 1 set of flotation vessels passes distributors on No. 2 set, the concentrates joining up and passing to the de-waterer. The spigots of No. 2 set of flotation vessels join up with the spigots of No. 2 set of No. 1 unit, and pass to the settlers (I). The molybdenite concentrates also join up with that produced from No. 1 sub-unit, and together pass to the de-waterer.

The molybdenite de-waterer is a rectangular box approximately 3 ft. long by 2 ft. wide and 6 in. deep. On the bottom of the box is placed 80-mesh screening. The liquor carrying the concentrates is led on to the box, the latter being given a shaking movement. The de-watered concentrate is periodically removed from the screen, the liquor and fine molybdenite passing through the screen into a large 3-compartment box. The fine molybdenite settles in this box, and the liquor overflows to the storage reservoir. The fine molybdenite in No. 1 compartment of this box is periodically removed and dressed in "kieves" to a marketable concentrate.

The fine molybdenite in Nos. 2 and 3 compartments, together with the skimmings from the kieves, are periodically returned to the mixers. As much as possible of the liquor is saved and pumped from the storage reservoir to tanks above the mixers, thus providing liquor for the mixers and "overflow" of the flotation vessels. Loss in liquor is provided for by adding water when necessary to these tanks.

The de-watered molybdenite concentrate is dried and is then ready for market. The concentrate obtained from the screen assays 85 % to 94 % MoS_2. The dressed concentrate from No. 1 compartment of the "box" assays 80 % to 85 % MoS_2, depending on the cleanliness of the water used in the flotation plant and the nature of the ore milled.

MILL WATER SUPPLY.

Water for milling and concentrating is obtained from the Stony Creek dam. This is situated about 1¼ miles from the mill, and at present has a capacity of approximately 10,000,000 gals. A 4-in. pipe line delivers water to the mill reservoir, having a "head" of approximately 20 ft., from whence it is drawn for milling. From the outlet of the mill reservoir to the entrance to the stamper boxes there is a "head" of 5 ft., and to No. 1 set of classifiers 10 ft.

All overflow water is sent to the mill creek dam, and after settlement is pumped back to the mill reservoir.

CHEMICAL LABORATORY.

Mine samples are assayed in 100-ton lots for WO_3, MoS_2, and Bi. Battery pulp samples are assayed daily for WO_3, MoS_2, and Bi, with an average check sample at the close of each periodical clean-up. This sample is weighed out from the "daily pulps" according to tonnage crushed each day. It is also assayed for WO_3, MoS_2, and Bi. The bismuth–wolfram concentrates from the Wilfley and Krupp tables and the vanners are assayed for WO_3 and Bi. Molybdenite concentrates are assayed for MoS_2, with a check for insoluble. Separated wolfram or bismuth concentrates are assayed for WO_3 and Bi. All samples for WO_3 are done by the acid method. Mine and battery pulp samples are done colorimetrically for both MoS_2 and Bi. Molybdenite concentrates are done volumetrically for MoS_2. Bismuth in concentrates is done gravimetrically from the acid solution from WO_3. Occasionally a gravimetric check is done for MoS_2 and Bi in mine and battery pulp samples.

The following are the methods used in the chemical laboratory :—

Acid Method of Estimation of WO_3 in Concentrates and Ores.—It is most important that the ore be finely ground. Treat .5 grm. of the concentrates with 60 cc. of HCL, having the beaker covered with a watch-glass. Digest from 2½ to 3 hours, with further additions of HCL as solution evaporates down to small bulk. Add 25 cc. concentrated HNO_3, and evaporate down to about 10 cc. (It is best not to heat to dryness, as there is danger of overheating the residue and causing the tungstic acid to be insoluble in ammonia.) Take up the residue with 50 cc. of hot water and let stand for about three hours. Filter and wash well with hot water.

The residue in the beaker is now treated with about 50 cc. NH_4OH (1–1), to which 1 cc. of strong HCL has been added. Solution is filtered and washed, then transferred to a weighed porcelain dish and evaporated to dryness. The dish is then heated (gently at first) to expel all NH_3 salt, and the residue weighed as WO_3.

Colorimetric Estimation of Bismuth.—Weigh out .05 grm. of finely-ground ore for 3 % Bi or over, or .5 grm. for under ; transfer to 500 cc. graduated flask, add 25 cc. HNO_3 and 75 cc. water, and boil 10 minutes ; cool, fill up to mark with water, mix thoroughly, and filter about 100 cc. into dry flask. Fill burette with the solution, which is now ready to compare with a standard solution of bismuth. Fill a similar burette to the one used with standard Bi solution and run exactly 1 cc. into 50 cc. Nessler tube, together with 10 cc. of a 10 % solution of KI and 3 drops of H_2SO_3. To a second Nessler tube add 10 cc. KI solution and 3 drops of H_2SO_3, and then run in sample until approximately the same depth of yellow colour is obtained as is contained in the standard tube: then read off the burette. If this was 5.0 cc., and 0.5 grm. of ore had been taken, the result would be 10 % bismuth.

Standard Bismuth Solution.—Weigh out accurately .025 grm. pure metallic bismuth; transfer to 500 cc. graduated flask, add 25 cc. HNO_3 and 75 cc. H_2O. Boil gently 10 minutes, cool, make up to mark with H_2O, and mix; 1 cc. of this solution equals .00005 grm. bismuth.

Calculation.—Divide the 500 cc. by cc. consumed of sample, and multiply by value of 1 cc. of standard, which in this case is equal to .00005 grm. Bi; this, multiplied by 2000, will give the percentage.

Colorimetric Estimation of Molybdenite.—Weigh out 1 grm. of the finely-ground ore and treat with *Aqua regia.* The solution is repeatedly evaporated to small bulk with HNO_3, and then continuously evaporated to a pasty consistency. Add 30 cc. water and 10 cc. HCL, warm, stir till clear, add 15 cc. NH_4OH, and boil for a few minutes; filter into a 250 cc. flask, wash precipitate on filter with hot water, make the solution just acid with acetic acid, then add 10 cc. strong acetic acid in excess; cool, make up to the mark, and mix.

The solution is now ready for comparison with a standard ammonium molybdate solution.

Standard Ammonium Molybdate Solution.—Deliver 2 cc. of ordinary molybdate solution, as used for estimating lead (9 grm. per litre) into 250 cc. graduated flask, add 20 cc. HCL and 30 cc. NH_4OH, and boil for a few minutes, to obtain approximately the same conditions as in sample. Make just acid with acetic acid, and add 10 cc. acetic acid in excess; cool, make up to mark, and mix. The solution is now ready for comparison with the solution.

Color Comparison.—Make up a fresh solution of tannic acid, .5 grm. to 100 cc., and fill up a burette with the standard, a second with the sample, a third with tannic acid : run 2 cc. of standard and 2 cc. of tannic into a 50 cc. Nessler tube ; dilute to mark and mix gently. To a second Nessler tube deliver 2 cc. tannic acid, and then run in sample until the same colour is obtained.

Calculation.—The value of the standard molybdate solution is calculated as follows :—The ordinary molybdate solution is usually standardized against .3 grm. lead sulphate, which consumed, say, 20 cc. of it ; .3 grm. lead sulphate is equal to .1584 MoS_2 ; therefore, 2 cc. = .01584 grm. MoS_2. This is the total value of the 250 cc. kept as a standard. .01584 ÷ 125 gives the value of 2 cc., the amount used in the Nessler tube for comparison—viz., .0001267 MoS_2 ; thus, if 8 cc. of sample prepared from 1 grm. of ore were consumed, the result would be .39 per cent. MoS_2 ; 2 cc. is chosen as giving a convenient colour, and maintained as far as possible for convenience of memory.

This method is one written by G. Spurge, F.C.S., and is found to give good results on low-grade ores, battery "pulps," and "tails."

Estimation of Bismuth in Bismuth-Wolfram Concentrates.—The wolfram is estimated as formerly stated. The filtrate, after filtering off the tungstic acid, is evaporated to a small bulk, and the HNO_3 expelled by additions of HCL and boiling. Owing to the absence of Pb in the concentrates, no H_2SO_4 is required to convert Pb into $PbSO_4$. Dilute the solution and pass in H_2S to saturation.

Bi, together with AS, Sb, Mo, &c., if present, are precipitated as sulphides. Filter and wash thoroughly with hot water. A hot solution of KCN is then passed through the precipitate, when the impurities are dissolved out, leaving the bismuth sulphide undissolved. Wash with hot water, dissolve in HNO_3 (1-1), dilute a little, and then boil. Partially neutralize the solution with NH_2CH, but without producing any permanent precipitate, and then add a solution of $(NH_4)_2CO_3$ in very slight excess. Allow the solution to stand on a hot plate for some time until the bismuth carbonate has settled. Filter and wash with hot water. Dry the precipitate and ignite in a weighed porcelain crucible, first removing the precipitate from the filter paper, which is burnt to an ash, then adding the precipitate. Ignite at a low, red heat, cool, and weigh as Bi_2O_3.

Volumetric Estimation of Molybydenite.—1 grm. of the ore is weighed out and treated with HNO_3 and a little HCL, the MoS_2 being converted into molybdic acid. The solution is repeatedly evaporated to small bulk with HNO_3, and then continuously evaporated to a pasty consistency.

The residue is extracted with NH_4OH, the solution boiled, then filtered, washing the residue well with hot water. The solution is made up to 250 cc. and mixed thoroughly ; 20 cc. of standard lead sulphate solution (measured from burette) are taken, acidified with acetic acid, diluted to 100 cc., and boiled. This solution is then titrated with the assay solution until a faint yellow tinge is obtained, using tannic acid solution as indicator (usual volumetric method for Pb).

On the basis of 1 grm. taken, the reading obtained, less .2 cc., divided into 1978.75, gives the percentage of MoS_2.

Preparation of Standard Lead Sulplate.—Weigh out 7.5 grm. of pure dry $PbSO_4$; take up with 400 cc. of ammonium acetate (slightly acid with acetic), and dilute to 1 litre.

When dealing with rich molybdenite concentrates, take 40 cc. of $PbSO_4$ solution instead of 20 cc ; note reading, deduct .2 cc., and divide by 2 before dividing into 1978.75.

The filter paper containing $FeSiO_2$, &c., can be dried, ignited, and weighed as a rough check against the figures. The addition of percentage of insoluble and MoS_2 giving approximately 99 %.

The writer, who is mine and mill superintendent at Wolfram, desires to thank the following :—Mr. F. C. Newman, general manager, for kind permission to publish the paper ; Mr. O. M. Williams, mine surveyor, for the preparation of the flow sheets ; and Mr. Wm. Poole, Sydney, for the revision of the paper and many valuable suggestions.

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PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy

(INCORPORATED).

NEW SERIES.

No. 41.

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

31st MARCH, 1921.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY (INCORPORATED), MELBOURNE.

Australasian Institute of Mining and Metallurgy

(INCORPORATED).

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Colin Fraser, S.A.

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D. L. Stirling, Melbourne, Vic.

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South Australia	H. W. Gartrell, The University, Adelaide.
New South Wales	F. Danvers Power, Sydney.
Western Australia	F. W. R. Godden, Hampton Plains.
New Zealand	D. B. Waters, Dunedin.
Tasmania	Russell M. Murray, Mount Lyell.
North Queensland	Murray Russell, Brisbane.

BRANCH SECRETARIES:

Sydney	F. Danvers Power, 33-39 Hunter Street, Sydney, N.S.W.
Kalgoorlie	F. W. R. Godden, Hampton Plains.
Broken Hill	C. H. J. Clayton, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. Patterson, Mount Morgan, Q.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 Queen Street, Melbourne, Victoria.

Institute Matters.

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MINUTES OF MEETINGS.

OF THE INSTITUTE.

ANNUAL MEETING.

MELBOURNE, 21ST MARCH, 1921.

IN THE INSTITUTE ROOMS, 48 QUEEN STREET, AT 1 P.M.

Professor E. W. Skeats (Member of Council) occupied the chair.

The Secretary read the notice convening the meeting.

Minutes of the First Ordinary Meeting, 1920, were read and confirmed.

The Report of the Council and Balance Sheet for 1920 were submitted and adopted.

Messrs. Oxlade and Mackie were elected auditors for 1921 at a remuneration of £2 2s.

REPORT OF COUNCIL FOR 1920.

TO THE MEMBERS.

THE Council has pleasure in submitting its report for the past year.

Membership of the Institute now totals 616, made up as follows:—Life Members, 5; Members, 391; Associate Members, 159; Students, 61. Seventeen Members, 17 Associate Members, and 8 Students were admitted during the year. Five members resigned, 3 died, and 3 were reported killed in action during 1918. Four Associate Members were transferred to the grade of Member. The net gain was therefore 31.

The Council has, with deep regret, to record the loss the Institute has sustained on account of the death of six members, viz.:—M. O. Copland, H. E. Hammel, Douglas Marks, Philip A'Morley Parker, W. F. Smith, and A. E. Tandy. Maurice Osric Copland (B.M.E.), Member, was Principal of the Ballarat School of Mines at the time of his death, which occurred on 31st July, 1920, after a short illness. He was a graduate of the Melbourne University, and had practical experience in mining in the Walhalla district (Vic.), on the Rand, and in Western Australia. Going from the Kalgoorlie School of Mines about four years ago, Mr. Copland took great interest in experiments to test the suitability of Victorian clays for the manufacture of white earthenware. He gave enthusiastic assistance in the establishment of Repatriation classes at the Ballarat School of Mines. Philip A'Morley Parker (B.C.E.), Associate Member, died at Kuala Lumpur, Federated Malay States, on 4th August, 1920. He was a graduate of the Melbourne University, and left Australia some years ago to occupy the position of manager of the firm of J. A. Russell and Co., of Kuala Lumpur. He was with that firm at the time of his death. Douglas G. Marks, Student Member, was drowned at Palm Beach, Sydney, on 25th January, 1920, in a gallant attempt to rescue a bather in distress. He served with distinction in the Great War, and attained the rank of Lieut.-Colonel. Henry E.

Hammel (Lieut.) was reported killed in action on 22nd May, 1918. He was an Associate Member of the Institute. In 1913 he was on the staff of the Great Fitzroy Mines Ltd., Mount Chalmers, Queensland, and later with the Mount Morgan Co. W. F. Smith (Student) was reported killed in action in 1918. Previous to enlisting he was a student of the Charters Towers School of Mines, Charters Towers, Queensland. Arthur E. Tandy (Associate Member) was killed in action in France on 2nd April, 1918. His home was at "Glen Rowan," Warreemba-road, Abbotsford, N.S.W.

Two meetings of the Institute were held during the year—the Annual Meeting on 30th January, and the First Ordinary Meeting on 17th December. Disappointment was keenly felt on account of the Council being forced to abandon the long-looked-for visit to Port Pirie and Wallaroo and Moonta. Arrangements for this visit were well in hand, but the continuance of the regrettable strike at Broken Hill and the consequent cessation of operations at Port Pirie made the visit impossible.

The following Committees were appointed early in the year:—An Executive Committee, a Finance Committee, a Publication and Education Committee, a Branches Committee, and a Mining Managers' Certificates Committee.

Mr. J. M. Bridge was elected a member of the Council on 27th February.

Mr. W. G. Langford, of the Vailala Oilfields, Papua, was appointed local correspondent for Papua in June last.

Copies of the final draft of the proposed Memorandum and Articles of Association were issued to members on 1st November, together with a ballot paper, upon which members were requested to record their votes for or against the adoption of the proposed new constitution. The resolutions submitted, which were as follow, were unanimously adopted:—

> 1. That application be made to the Attorney-General of the State of Victoria for a licence directing that the Institute be reigstered under the "Companies Act 1915" of the State of Victoria as an Association not established for profit, and if and when such licence be obtained that the Institute be incorporated

under the said "Companies Act 1915" under the name of "Australasian Institute of Mining and Metallurgy Incorporated," and that steps be then taken to register the Institute in each of the other States and in the Dominion of New Zealand.

2. That the draft Memorandum of Association submitted to the meeting, and for the purpose of identification subscribed by the chairman thereof, be and the same is hereby approved as the Memorandum of Association in pursuance of which the Institute shall be incorporated.

3. That the Articles of Association contained in the draft submitted to the meeting, and for the purpose of identification subscribed by the chairman thereof, be and the same are hereby approved and that such Articles be and they are hereby adopted as the Articles of Association of the Institute to the exclusion of and in substitution for all existing rules of the Institute.

4. That if any modifications or amendments be required to be made in the said draft Memorandum of Association and draft Articles of Association in order to obtain the licence of the Attorney-General or in order to comply with the "Companies Act 1915," the Council of the Institute shall be and they are hereby expressly authorized to make such modifications or amendments.

Application for registration was made forthwith, and it is expected that a certificate of incorporation will be granted by the Minister early in 1921. As soon as this is received registration in the other States and in New Zealand will be proceeded with. Under incorporation the Institute's status should be considerably improved, and its scope and influence much extended. A perusal of the Memorandum and Articles of Association will show that every branch of the mining industry is provided for. The special provisions for the formation of branches in every mining centre should be welcomed, as there is ample scope for further extension and useful work—not only in the various metalliferous districts, but in the coal-mining centres of Australasia.

The Institute of Science and Industry notified the Australasian Institute of Mining and Metallurgy during the year that it would be pleased to arrange for the mining industry to be represented on any committees in which members of the Australasian Institute of Mining and Metallurgy are particularly interested.

The fund inaugurated by Mr. J. W. Sutherland last year for the purpose of encouraging students in mining and metallurgy by means of prizes or medals or for helping to forward any of the objects of the Institute was increased by £100 during the year 1920 through the generosity of Messrs. G. H. Blakemore and W. E. Wainwright, each of whom donated £50. A decision in regard to the allocation of this fund will shortly be made.

At the invitation of the Melbourne University, Mr. G. C. Klug was appointed to represent the Institute on the Engineering Faculty of the University.

The Institute Employment Register was considerably extended during the year, and, with the co-operation of mining companies, this department should be of practical assistance not only to members but to companies.

The Institute accepted the invitation of the Royal College of Science and Technology to represent that body in Australasia in the matter of Frecheville Research Fellowships of the Royal School of Mines, London. Members of the Institute and lecturers at Universities and Schools of Mines were accordingly supplied with full particulars regarding these fellowships. The Council has now pleasure in reporting that Mr. J. A. Dunn (B.Sc., Melb.), a Student Member of the Institute, was appointed a Frecheville Fellow during the year for research work in connection with the relation existing between country rocks and enclosed deposits.

A Government Bill for the registration of architects was submitted to the Victorian Legislative Assembly in August last, and steps were taken by the Council to have certain amendments made to the measure to safeguard the rights of members of the Institute.

The establishment of a register of mining engineers, duly qualified to practise as such, is one of the objects of the Institute under its new constitution. This subject received consideration during the year, and it is expected that progress will shortly be made in this matter in co-operation with the Institution of Engineers.

The question of federation with the recently-formed Institution of Engineers of Australia is under consideration, and in connection therewith a suggestion has recently been brought under the notice of the Council by the Institution of Engineers. Briefly, the proposal is for the formation of an Engineering Council composed of representatives of Australasian technical associations, such as the Australasian Institute of Mining and Metallurgy, the Institute of Engineers of Australia, and the Australian Chemical Institute. The Council has expressed itself in favour of some such scheme, and has suggested that a conference be convened to consider the matter.

The standardization of examinations for mining managers' certificates in the various Australasian States has been considered by the Mining Managers' Certificates Committee, and the request has been made to the Premier of Victoria that he submit the suggestion to the next conference of Premiers that an inter-State conference of Chief Inspectors of Mines be held with a view to drafting a Bill to provide for uniform standards of examination for mining managers' certificates and for reciprocity between the States.

Representatives of the Institute were appointed, in October last, on the Council of the Hobart meeting of the Australasian Association for the Advancement of Science.

A proposal was submitted to the Council during the year that provision be made for the admission to the Institute, as Members or Associate Members, of persons occupying the position of mining or metallurgical accountants of large corporations. The question has been submitted to members of Council for ballot.

The possibility of the introduction of legislation into Australia providing for the withdrawal from use of reciprocating rock-drills was brought under the notice of the Council by the Broken Hill Branch. The Council resolved that steps be taken to oppose any legislation that may be contemplated which would debar the management of mines from using their own judgment in the selection and use of any drill, provided the desired results were achieved.

Steps were taken during the year to suppress the publication and issue of statements concerning the values of ore reserves which were considered to be misleading. In the matter the Council secured the co-operation of the Australian Mines and Metals Association.

During the visit of the Prince of Wales to Australia an address of welcome, on behalf of the Institute, was presented to His Royal Highness; and the following acknowledgment, on behalf of the Prince, was subsequently received:—

MELBOURNE,
26*th May*, 1920.

THE PRESIDENT,
AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY.
SIR,

I am directed by the Prince of Wales to convey to you his sincere thanks for the loyal address of welcome presented by you yesterday on behalf of the Australasian Institute of Mining and Metallurgy. His Royal Highness is very sensible of the important service done by the mining engineers and metallurgists of the British Empire, and knows that they have played an important part in developing the mineral wealth of Australia. He thanks you for your good wishes, and will be happy to convey your assurances of devotion to His Majesty the King.

I am,
Your obedient servant,
(Sgd.) E. W. M. GRIGG,
Lieut-Colonel,
Secretary to H.R.H. the Prince of Wales.

AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY.

Balance Sheet, 31st December, 1920.

LIABILITIES.

Subscriptions paid in advance				£44	6	1
Donation Trust A/c				152	15	0
Life Membership				15	15	0
Accumulated Fund—						
Balance at 31st Dec., 1919	£1578	17	7			
Add Surplus transferred from Revenue A/c ...	377	13	5	1956	11	0
				£2169	7	1

ASSETS.

State Savings Bank at Credit	£234	9	7			
Commonwealth Savings Bank at Credit	66	19	1	£301	8	8
Commonwealth of Australia War Loans (at cost) ...	1239	7	6			
Commonwealth of Australia Second Peace Loan (at cost)	200	0	0			
Commonwealth of Australia War Savings Certificates (at face value)	185	0	0	1624	7	6
Outstanding Subscriptions				190	0	0
Sundry Debtors				10	0	0
Office Furniture, Melbourne and Broken Hill Branch				43	10	11
				£2169	7	1

Melbourne, 1st *March*, 1921. Audited and found correct. Oxlade & Mackie, Auditors.

Statement of Receipts and Expenditure for the Year ended 31st December, 1920.

RECEIPTS.

	£	s.	d.	£	s.	d.
Dec. 31st, 1919.						
To Commonwealth Savings Bank at Credit ...	£104	15	1			
State Savings Bank at Credit	224	4	7			
				£328	19	8
Dec. 31st, 1920.						
Members' Subs., 1917 ...	2	2	0			
,, ,, 1918 ...	6	7	0			
,, ,, 1919 ...	101	10	1			
,, ,, 1920 ...	744	5	3			
,, ,, 1921 ...	39	11	7			
,, ,, 1922 ...	2	2	0			
,, ,, 1923 ...	2	2	0			
				897	19	11
Life Membership ...	15	15	0			
Entrance Fees	57	16	6			
Advertisements ...	39	0	0			
Sales	5	3	0			
Donations	100	5	0			
Interest—Commonwealth Savings Bank ...	4	9	7			
Interest—State Savings Bank	10	5	0			
Interest—War Loans ...	70	5	0			
				302	19	1
				£1529	18	8

EXPENDITURE.

	£	s.	d.	£	s.	d.
Dec., 31st, 1920						
By Printing & Stationery ...	£40	6	10			
Rent	50	0	0			
Salaries	276	0	0			
Postages, Telegrams, &c.	65	18	2			
Sundries	43	17	11			
Proceedings	226	0	1			
Commission	6	19	6			
Meeting Expenses ...	20	0	0			
				729	2	6
Commonwealth War Loan	239	7	6			
Commonwealth Peace Loan	200	0	0			
Commonwealth of Australia War Saving Certificates (Face Value)	60	0	0			
				499	7	6
Commonwealth Savings Bank at Credit ...	66	19	1			
State Savings Bank at Credit	234	9	7			
				301	8	8
				£1529	18	8

Revenue Account for the Year ended 31st December, 1920.

1920.							
Dec. 31.	To Publications	£176	0	1			
	Stationery & Printing ...	40	6	10			
	Postages, Telegrams, &c....	65	18	2			
	Salaries ...	276	0	0			
	Rent . .	50	0	0			
	Sundries ...	43	17	11			
	Commission	6	19	6			
					£659	2	6
	Balance transferred to Accumulated Fund ...				377	13	5
					£1036	15	11

1920.							
Dec. 31.	By Subs., 1917 ...	£2	2	0			
	,, 1918 ...	6	7	0			
	,, 1919 ...	101	10	1			
	,, 1920 ...	746	7	9			
	Advertisements	32	10	0			
	Sales ...	5	3	0			
	Entrance Fees	57	16	6			
	Interest ...	84	19	7			
					1036	15	11
					£1036	15	11

Melbourne, 1st *March*, 1921. Audited and found correct. Oxlade & Mackie, *Auditors*.

OF THE COUNCIL.

February 28th, 1921—1 p.m. (Special Meeting).

A letter was submitted from the Solicitors (Messrs. Blake and Riggall), intimating that the Minister, Crown Law Department, would be prepared to issue a certificate of incorporation subject to the following amendment to Clause 4 of the Memorandum of Association :—

> "In Clause 4 of the Memorandum of Association delete the words 'Provided that nothing . . . . . for distinguished services' and in lieu thereof substitute 'Provided that nothing herein contained shall prevent the payment in good faith of remuneration to any officers or servants of the Institute or other person not being a member of the Institute in return for any services actually rendered to the Institute'."

Resolved that the alterations required by the Crown Law Department be accepted.

OF THE EXECUTIVE COMMITTEE.

(Summary)

February 14th, 1921—1 p.m.

Professor R. W. Chapman (President) occupied the chair.

Minutes of previous meeting were read and confirmed.

The Secretary's Report was presented, and showed that receipts since last meeting were £76 15s. 6d, and for 1920 £1196.

Accounts to the amount of £18, including Petty Cash advance 1921 (£10), were passed for payment.

Instructions were given in regard to signatures for cheques drawn on the Institute's account.

The Finance Committee was requested to report on the whole question of Finance, Securities, etc.

Leave of absence from Council meetings was granted to Mr. H. Herman to enable him to visit Great Britain and Europe.

Nomination of Mr. James Conway of the State Coal Mine, Bowen, Queensland, as a member, was approved for ballot.

Resignation of Mr. John Cunningham was accepted.

The Report of the Publication Committee approving of the publication of a paper by Mr. W. H. Bowater entitled "Treatment of Wolfram, Bismuth and Molybdenite Ores at Burma-Queensland Corporation Mill, Wolfram, N.Q.," was adopted.

Mr. H. W. Gartrell, Adelaide University, was appointed Local Correspondent for South Australia.

Allocation of Donation Fund was referred to the Publication and Education Committee for report.

A letter was read from the Institution of Engineers of Australia enclosing copy of a paragraph which appeared in the "Chemical Engineering and Mining Journal" of 5th December, 1920, suggesting the formation of a Federal Council composed of representatives of the Institution of Engineers, the Australasian Institute of Mining and Metallurgy and the Australian Chemical Institute. After discussion it was resolved:—

> "That the Institution of Engineers be informed that the Australian Institute of M. & M. is fully in accord with the views expressed in the paragraph referred to and is prepared to appoint delegates to attend a conference on the subject convened by the Institution of Engineers when the time is opportune."

A sub-committee, consisting of Messrs. G. C. Klug, Colin Fraser, and A. S. Kenyon was appointed to deal with the draft Bill providing for the Registration of Engineers when received from the Institution of Engineers, and authorised to call a Special Meeting of the Council if necessary to consider the question.

A record of the votes of members of Council on the question of the admission of Mining Accountants as Members, etc., was submitted and showed that the majority was against such admission.

Consideration of the date and locality of the First Ordinary Meeting, 1921, was postponed.

Resolved that a copy of the "Mineral Industry" be purchased.

The nomination of Messrs. R. C. Sticht and G. C. Klug to represent Mining and Metallurgy on the Committee of Science and Research under the auspices of the Australasian Association for the Advancement of Science was approved.

Mr. D. L. Stirling was appointed Secretary, in accordance with Article 54 of the Memorandum and Articles of Association.

Mr. A. S. Kenyon was appointed Hon. Treasurer, as provided by Article 56.

March 14th, 1921—7 p.m.

Minutes of the previous meeting were read and confirmed.

The Secretary's Report was presented and showed that receipts since last meeting were—Subscriptions £159 9s. 8d., Sales £1.

Accounts to the amount of £101 were passed for payment.

Nomination of Dr. F. L. Stillwell as a Member was approved.

The Chairman declared the following elected to the Institute by ballot of Members of Council:—As Members—Messrs. William Ernest Barrow, William Henry Charles Chapple, William Nelson Cranz, Loftus Hills, George Alan More, and Percy Rawlings Osborne; as Associate Members—Messrs. Eric E. G. Boyd, John Alexander Dunn, William Gray, John Noall, Frederick Valentine Ramsden and Charles G. L. Thompson.

The names of members whose subscriptions were in arrears were removed from the register in accordance with Article 33.

A suggestion was submitted that a new style of nomination form be adopted. The suggestion was referred to a Sub-Committee.

A report on the subject of drilling machines in use in South Africa was referred to the Secretary of the Broken Hill Branch.

It was resolved that the Sydney Branch be communicated with in regard to the possibility of holding the First Ordinary Meeting 1921 at Sydney and Port Kembla.

A draft of the Annual Report of the Council for 1920 was submitted and, after revision, was approved.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays an Public Holiays.

MEMBERSHIP.

Since the last issue of Proceedings, the following have been admitted to the Institute:—

Members.

Names and Addresses.

BARRON, WILLIAM ERNEST, Rhodesia Broken Hill Development Co. Ltd., Broken Hill, N. Rhodesia.

CHAPPLE, WILLIAM HENRY CHARLES, Great Cobar Ltd., Cobar, N.S.W.

CONWAY, JAMES, State Coal Mine, Bowen, Q.

CRANZ, WILLIAM NELSON, Broken Hill Proprietary Ltd., Broken Hill, N.S.W.

HILLS, LOFTUS, Geological Survey Office, Launceston, Tas.

MORE, GEORGE ALAN, c/o Messrs. Sime, Darby & Co. Ltd., Singapore, Fed. Malay States.

OSBORNE, PERCY RAWLINGS, Port Moresby, Papua.

Associate Members.

BOYD, ERIC EWART GLADSTONE, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.

DUNN, JOHN ALEXANDER, c/o Imperial College of Science and Technology, South Kensington, London, S.W.7.

GRAY, WILLIAM, c/o Anglo-Persian Oil Co. Ltd., c/o Whitten Bros., Port Moresby, Papua.

NOALL, JOHN, c/o Pahang Consolidated Co. Ltd., Sungei Lembing, Kuantan, Singapore, Fed. Malay States.

RAMSDEN, FREDERICK VALENTINE, c/o J. W. Dudgeon, Scottish House, William Street, Melbourne, Vic.

THOMPSON, CHARLES GEORGE LANFEAR, New Guinea Copper Mines Ltd., Port Moresby, Papua.

Applications for admission to the Institute have been received from the following:—As Members—HECTOR JOHN HARRISON, 656 Chapple Street. Broken Hill, N.S.W.; FRANK LESLIE

Stillwell, d.sc., c/o Bendigo Amalgamated Goldfields N.L., Bendigo, Vic. As Associate Member—John Lemon Sampson, c/o Broken Hill Associated Smelters Ltd., Port Pirie, S.A.

LIST OF MEMBERS.

A list of members is included in this number. Members are requested to promptly notify the Secretary of any changes of addresses.

INCORPORATION.

The Registrar-General has signified his approval of the Memorandum and Articles of Association, and will issue a certificate of incorporation early in April. A copy of the Memorandum and Articles of Association is attached to this issue.

LOCAL CORRESPONDENT.

Mr. H. W. Gartnell (Member) of the University, Adelaide, S.A., has been appointed Local Correspondent for South Australia.

DONATION.

Mr. H. H. Schlapp (Member) Melbourne, has kindly donated the following publications to the Institute, viz., Transactions, American Institute of Mining and Metallurgical Engineers, vols. 26 to 62.

MOVEMENTS OF MEMBERS.

A. D. Combe has received an appointment as Assistant Geologist in Uganda, British East Africa, and recently left Australia to take over his new duties.

G. D. Delprat, member of Council and Past President, who has been General Manager of the Broken Hill Proprietary Co. Ltd. since 1898, has resigned, and is now consulting Engineer to that company.

Clem. A. Hack, of Melbourne, is on a visit to the United States of America.

John Joice, late of Southern Cross, W.A., has been appointed Assistant Manager of the Raub Australian G.M. Co. Ltd., Raub, Pahang, Fed. Malay States.

W. J. LAKELAND (Capt.) has returned to Ballarat (Vic.) after serving with distinction in the great war. Prior to enlisting, he was with the Burma Mines Ltd.

ESSINGTON LEWIS has been appointed General Manager of the Broken Hill Proprietary Co. Ltd. in place of Mr. G. D. Delprat, who recently resigned.

CYRIL B. MARRYAT is on the staff of the National Physical Laboratory, Teddington, Middlesex, England. He left Australia on active service in 1916. Later he was declared medically unfit, and was discharged to take up Scientific and Industrial Research work (under Australian munition workers) at the National Physical Laboratory as junior volunteer assistant.

M. R. McKEOWN has been appointed manager of the New Gulgong Deep Lead G.M. Co. He was formerly at Vegetable Creek, N.S.W.

PROFESSOR E. W. SKEATS, D.SC. (Member of Council) has returned to Melbourne from a visit to Great Britain and America.

OWEN B. WILLIAMS, late of the Block 10 Mine, Broken Hill, is now General Manager of the North Mount Farrell Co. Ltd., Tullah, Tas.

F. G. WILSON has been appointed General Manager of the Austral Siamese Company's works at Sutherland's Water, N.S.W.

R. J. WINTERS, late of Newtown, Sydney, N.S.W., has been appointed Geologist to the Protectorate of Uganda, British East Africa. His address is—c/o Government Geologist, Entebbe, Uganda, British East Africa.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY

From 31st December, 1920 to 31st March, 1921.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
Institute of Science and Industry : Report on Compulsory Adoption of Metric System in the United Kingdom		Melbourne
Department of Mines, Victoria : Geological Survey, Bulletin No. 43		Melbourne
Department of Mines, New South Wales : Records of the Geological Survey, Vol. IX., Part 2		Sydney
Royal Society of New South Wales : Journal and Proceedings, Vol. LIII.		Sydney

Government Geologist, West Australia :	
Bulletin, No. 83 - - - -	Perth
Department of Mines, Tasmania :	
Report on the Investigation of the Tin Bearing Ores of the Renison Bell District - -	Hobart
Royal Society of Tasmania :	
Papers and Proceedings, Vol. XLIV. -	Hobart
New Zealand Journal of Science and Technology :	
The Tangaraka Coalfield, North Taranaki, by P. G. Morgan.	
Geological Features Disclosed by Excavations at the Proposed Dam Site at Arapuni, by J. S. Henderson.	
Avoca or Whatarama District—Mount Torlesse Colleries, &c., by P. G. Morgan - -	Wellington
Institution of Mining and Metallurgy :	
Bulletins, Nos. 195-197 - - -	London
Institution of Mining Engineers :	
Transactions, Vol. LIX., Part 6 - -	London
Geological Society :	
Quarterly Journal Nos. 302 and 303 - -	London
Geologists' Association :	
Proceedings, Vol. XXXI., Part 4, Vol. XXXIII., Part 1 - - - - -	London
Institute of Chemistry of Great Britain and Ireland :	
Proceedings, Vol. VI., Part 1. - -	London
Iron and Steel Institute :	
Journal, Vol. CI., No. 1, CII., No. II. -	London
Geological Survey of Great Britain :	
Memoirs, 1919 - - - -	London
Royal Dublin Society :	
Economic Proceedings, Vol. II., No. 15	
Scientific Proceedings, Vol. XV., No. 49, Vol. XVI., Nos 1-13 - - - -	Dublin
Annales des Mines :	
Vol. X., Parts 9-12 - - - -	Paris
Societa Geologica Italiano :	
Bulletin, Vol. XXXVIX., Parts 1 and 2 -	Rome
Geological Survey of India :	
Records, Vol. LI., Part 2 - - -	Calcutta

Department of Mines, Canada :
Annual Report 1920, Parts I., IV. and VI.
Bulletin, No. 32
Report on Road Materials along St. Lawrence Road
The Production of Iron and Steel in Canada, 1919
Phosphate in Canada - - - Toronto

United States Geological Survey :
Mineral Resources—1915, Part 1, Nos. 1-28, Part II, Nos. 18-35 ; 1916, Part 1, Nos 1-23, Part II. Nos. 1-36 ; 1917, Part 1, Nos. 1-29, Part II, Nos. 1-23 ; 1918, Part I, Nos. 1-28, Part II, Nos. 14-34 : 1919, Part 1, Nos. 1-5, Part II, Nos. 1-3
Water Supply Papers—Nos. 361, 362, 380-382, 389-391, 394, 396, 400-404, 406-410, 412-415, 417-421, 423-426, 428, 430-435, 438, 439, 441, 445, 448, 450-452, 454, 458, 474, 494.
Bulletins—Nos. 567, 620, 623-625, 637, 639, 640 FHJKL, 641 G-L, 642, 644, 647, 648, 650, 651, 654-58, 660 A-HJ, 661 A-EGHI, 662, 663, 665-67, 670-72, 681, 684, 690 A-E, 691 A-DH, 692, 694-96, 699-701, 710 CDFG, 711 EFH, 715 A-F 716 A-C.
Professional Papers—93, 94, 96, 98 LORST, 99, 101, 105, 106, 108 ABCHJI, 111, 115-119, 120 BDEFGHK, 125 CD, 128 AD.
Mineral Resources—1914, 1915, 1916, 1919.
Annual Report of Director—1916-1919 - New York

American Institute of Mining and Metallurgical Engineers :
Bulletin, Nos. 167-170. - - New York

California State Mining Bureau :
Bulletin, No. 88
Summary of Operations, California Oilfields, November and December, 1920
The Clay Industry in California - - Sacramento

Maryland Geological Survey :
Monographs—Cambrian and Ordovician - Baltimore

Smithsonian Institute :
Annual Reports, 1917 and 1918 - - Washington

Department of Mines, Mexico :
Bulletin, Vol. IX., Parts 5 and 6, Vol. X., Parts 1 and 2 - - - - - Mexico

RECENT ARTICLES ON MINING MATTERS.

(31st December, 1920, to 31st March, 1921).

NOTE.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c., due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Transactions*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng. New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London.

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

MECHANICAL.

Patching the Roofs of Copper Reverberatory Furnaces. G. J. Young. (6) Oct. 23, 1920.

Bucket Dumping Device for Use on an Incline Shaft. J. B. Harper. (6) Oct. 30, 1920.

Stuck Steel. D. E. Dunn. (6) Nov. 6, 1920.

Repairing Broken Cam Shafts. G. J. Young. (6) Dec. 4, 1920.

Knocker for Cleaning Conveyor Belt. W. R. Canton. (6) Dec. 4, 1920.

A Crushed Ore Feeder Which is Economical of Head Room. H. A. Linke. (6) Jan. 8, 1921.

Repair of a Broken Jaw Crusher. W. R. Canton. (6) Jan. 29, 1921.

Steam Shovel Repairs. H. H. Hunner. (6) Feb. 12, 1921.

The Coefficient of Discharge of Elementary Nozzles. A. A. Jude. (37) Dec., 1920.

An Automatic Counting Machine for Checking Train Wagons. C. Brackenbury. (25) Bull. No. 194.

METALLURGICAL.

Determination of Low Percentages of Lead. J. H. Hastings. (6) Oct. 30, 1920.

Recovery of Silver from Manganese–Silver Ores. J. A. Carpenter. (6) Nov. 6, 1920.

Colburn Flotation Machine. (6) Nov. 6, 1920.

Amalgamation in Tube Mills. (6) Nov. 20, 1920.

Smelter Laboratory of the United Verde Extension. H. O. Hammond. (6) Nov. 20, 1920.

Copper Losses in Slags. F. E. Lathe. (6) Dec. 4, 1920.

The Judge Electrolytic Zinc Plant. G. C. Heikes. (6) Dec. 11, 1920.

Surface Energies in Flotation. F. G. Moses. (6) Jan. 1, 1921.

Settling Flotation Concentrates. G. L. Schmutz. (6) Jan. 1, 1921.

Sidelights on the Cyanidation Process. A. James. (6) Jan. 15, 1921.

Selective Converting at Clifton, Arizona. J. O. Ambler. (6) Feb. 5, 1921.

Zinc Oxide Plant of the Utah Zinc Company. A. B. Parsons. (8) Nov. 27, 1920.

A Résumé of Literature on the Theory of Flotation, with Critical Notes. H. R. Adam. (8 Nov. 27, 1920.

Electrolytic Zinc Methods. H. R. Hanley. (8) Dec. 4, 1920.

Milling Practice at the Benguet Consolidated Mine. C. M. Eye and M. F. Dodd. (8) Serial commenced Dec. 4, 1920.

Methods of Ore-Sampling in Montana. H. B. Pulsifer. (8) Serial commenced Dec. 18, 1920.

Objectionable Practices of Minerals Separation. G. L. Nye. (8) Dec. 18, 1920.

The Mechanism of the Surface Phenomena of Flotation. I. Langmuir. (8) Dec. 25, 1920.

Sundry Details of Sampling at the Garfield Smelter. A. B. Parsons. (8) Jan. 1, 1921.

The Bunker Hill Smelter. T. A. Rickard. (8) Jan. 8, 1921.

The Greenawalt Sintering Process. W. E. Greenawalt. (8) Jan. 15, 1921.

Store-Bin with Louvred Hoppers. N. L. Hall. (8) Jan. 15, 1921.

Metallurgical Methods at Rio Tinto. C. De Kalb. (8) Feb. 5, 1921.

Consumption of Re-Agents Used in Flotation. T. Varley. (8) Feb. 19, 1921.

Metallurgical Operations of the Judge Mining and Smelting Co. A. B. Parsons. (8) Jan. 29, 1921.

Lead Salts in the Cyanidation of Silver Ores. R. W. Perry. (8) Feb. 12, 1921.

Heap Leaching of Copper Ore at Bisbee. (8) Feb. 12, 1921.

The Theory of Flotation. R. S. Dean. (8) Feb. 26, 1921.

The Sampling and Estimation of Quicksilver Ore. C. N. Schuette. (8) Feb. 26, 1921.

New Method of Charging Reverberatory Furnaces. J. O. Adams. (6) Jan. 29, 1921.

Consumption of Re-Agents Used in Flotation. (6) Feb. 12, 1921.

Pyritic Smelting of Refractory Sulphides in Knudsen Furnace. E. H. Roble. (6) Feb. 12, 1921.

Converting High-Grade Matte in Magnesite-Lined Converters. H. C. Robson. (25) Bull. No. 194.

Chemical Methods of De-Aeration of Water or Solutions. H. A. White. (28) Dec., 1920.

Treatment of Antimonial Gold at the Globe and Phœnix Gold Mine, Southern Rhodesia. (28) Jan., 1920.

MINING.

Alterations in a Ventilation Shaft. J. H. Stovel. (6) Jan. 15, 1921.

Details of Shaft Lagging. J. L. Dynan. (6) Jan. 29, 1921.

Some Observations on Mining by the Open-cast or Stripping Method. R. E. Palmer. (25) Bull. No. 195.

Scheme for Working the City Deep Mine at a Depth of 7,000 Feet. E. H. Clifford. (25) Bull. No. 197.

Notes on Experiments on Ventilation Problems in Development Work on Mines. E. J. Laschinger. (28) Nov., 1920.

The Kata Thermometer and its Practical Uses in Mining. H. J. Ireland. (28) Nov., 1920.

MISCELLANEOUS.

M'Fadden Gold Bill. (6) Oct. 30, 1920; Nov. 6, 1920.

The Decline in Copper. (6) Oct. 30, 1920.

Wonbah Molybdenite Mine and Mill, Queensland. J. H. Reid. (6) Nov. 13, 1920.

Mineral Resources of the Dutch East Indies. (6) Dec. 4, 1920.

The Administration of the M'Fadden Bill. S. L. Wills. (6) Dec. 11, 1920.

Organization of Mine Surveying Work. F. L. Fisher. (6) Jan. 8, 1921.

Cost of Copper in 1921. E. E. Thum. (6) Jan. 15, 1921.

The Price of Gold. W. B. Chomley. (8) Oct. 30, 1920.

Fighting Mine Fires. H. J. Rahilly. (8) Oct. 30, 1920.

The Human Factor in Mine Management. S. A. Lewisohn. (8) Nov. 6, 1920.

The Bounty on Gold. (8) Nov. 13, 1920.

Report of the Special Gold Committee to the Secretary of the Treasury. (8) Nov. 13, 1920.

The Future of Copper. E. C. Holden. (8) Jan. 1, 1920.

The M'Fadden Bill. W. J. Loring. (8) Feb. 19, 1921.

The Licensing of Engineers. (8) Feb. 26, 1921; March 5, 1921.

The Education of the Mining Engineer. W. S. Weeks. (8) March 5, 1921.

A Method of Recording Geology in Development Work. C. E. Wuensch. (8) Feb. 12, 1921.

The World's Mining Industry in 1920. (6) Jan. 22, 1921.

The Mining and Milling of Fluorspar. J. M. Blayney. (6) Jan. 29, 1921.

The Birthday Tunnel and Williams's Fancy Mines, Berringa, Vic. W. Baragwanath. (10) Bull. No. 43.

Report on the Investigation of the Tin-Bearing Ores of the Renison Bell District. J. H. Levings. (15)

Geology and Mineral Resources of the North-West, Central, and Eastern Divisions, W.A. H. W. B. Talbot. (14) Bull. No. 83.

Fire-Damp Explosions. R. V. Wheeler. (26) Trans., Vol. LX., Part 2.

The Production and Transmission of Compressed Air in Mines. J. T. Pringle. (26) Vol. LX., Part 2.

Sterilization of Water by Chlorine Gas. J. S. Arthur. (37) Jan., 1921.

The Human Factor in Industry. A. Ramsay. (37) Jan., 1921.

Some Sources of Error in Alluvial Boring. E. J. Pryor. (25) Bull. No. 195.

The Standardization of Materials Employed in Mining and Milling Plants. E. A. Wraight. (25) Bull. No. 196.

LIST OF MEMBERS
OF THE
AUSTRALASIAN INSTITUTE OF MINING & METALLURGY
(INCORPORATED).

¶ Life member. F Foundation member. § Author of paper.

MEMBERS.

Names and Addresses.	Date of Election.
Adam, John, Sons of Gwalia Mine, Gwalia, W.A.	1910
Adams, Ernest F., Box 5, P.O., Thames, N.Z.	1900
Adams, James Henry, Thames, N.Z.	1911
Agnew, John A., 1 London Wall Buildings. London, E.C.	1909
§Allen, Francis Bowen, 33 Colin-street, West Perth, W.A.	1900
Anderson, J. R. V., School of Mines, Bendigo, Vic.	1910
§Aplin, Wm., Mt. Morgan Technical College, Mt. Morgan, Q.	1905
Armstrong, Andrew S., Rhodesian Lead and Zinc Syndicate, Broken Hill, Rhodesia, South Africa	1912
Ashcroft, J. W., c/o R. N. Kirk, 16 O'Connell-street, Sydney, N.S.W.	1903
§Atkinson, Alfred Ashley, Mines Department, Sydney, N.S.W.	1912
Avery, David, 360 Collins-street, Melbourne, Vic.	1920
Avery, John, Electrolytic Zinc Co. of Australasia Ltd., Hobart, Tas.	1912
Baker, William H., School of Mines, Thames, N.Z.	1911
Banks, Charles A., 36 Kensington-place, Nicola-street, Vancouver, B.C.	1911
§Banks, Edwin G., Box 28, P.O., Waihi, N.Z.	1910
Baragwanath, Wm., Geological Survey Office, Mines Depart., Melbourne, Vic.	1915
Barker, Geo., Rosebery, Tas.	1915
Barr, James (jun.), c/o J. A. Russell & Co., Kuala Lumper, Fed. Malay States	1913

Names and Addresses.	Date of Election.
Barron, William Ernest, Rhodesia Broken Hill D. Co., Broken Hill, Northern Rhodesia	1921
Barton, B. V., Rhodesia Broken Hill D. Co., Broken Hill, Northern Rhodesia.	1910
Basedow, Erwin, Pirie-street, Kent Town, S.A.	1906
Bassett, John, Hall-street, Hokitika, N.Z.	1911
Battens, Henry, Grenville United Mines Ltd., Camborne, Cornwall, England	1900
Beamish, W. A., Briseis Company, Derby, Tas.	1904
§Beaumont, Edwin K., "Kenilworth," 24 Lewis-street, Lamington-heights, Kalgoorlie, W.A.	1899
Beech, Harold, Sons of Gwalia Mine, Gwalia, W.A. ..	1919
§Bell, Dr. James Mackintosh, Old Burnside, Almonte, Ontario, Canada	1906
§Bellinger, H. C., 120 Broadway, New York, U.S.A. ..	1910
Bennett, V. C., Electrolytic Zinc Co. of Australasia Ltd., Collins House, 360 Collins-street, Melbourne, Vic. ..	1914
Bennie, Boyd, Inspector of Mines, Huntley, N.Z. ..	1911
Black, Robert S., Kalgurli G.M. Co., Fimiston, W.A. ..	1909
Blackett, Charles E., Golden Horseshoe Estates Co. Ltd., Boulder, W.A.	1909
¶§Blakemore, G. H., 4 Bridge-street, Sydney, N.S.W. ..	F.
§Bohm, Horace Sanford, "The Range," Rockhampton, Q...	1898
§Bowater, W. H., Thermo-Electric Ore Reduction Corporation Ltd., Wolfram, Q.	1910
Boyd, Adam A., Mount Morgan G.M. Co., Ltd., Mount Morgan, Q.	1906
Bradford, Leslie, Broken Hill Pty. Ltd., Iron and Steel Works, Newcastle, N.S.W.	1910
Bray, G. E., Charters Towers, Q.	1908
Brett, Henry Tyndall, Albany Chambers, Bulawayo, Rhodesia, South Africa	1912
Bridge, John M., 1 Kooyong-road, Armadale, Vic. ..	1907
§Brinsden, Frederick G., South Kalgurli Ltd., Fimiston, W.A.	1909
¶§Broome, George H., State Coal Mine, Wonthaggi, Vic. ..	1900
§Brown, George F. Campbell, Mount Morgan, Q.	1910
Brown, H. Wheeler, c/o Broken Hill Proprietary Ltd., Hummock Hill, S.A.	1913
Brown, Lionel Venn, "Ocean House," Moore-street, Sydney, N.S.W.	1920

Names and Adresses.	Date of Election
§**Browne, D. H.**, State Coal Mine, Wonthaggi, Vic. ..	F.
Buckley, Henry, Zinc Corporation Ltd., Broken Hill, N.S.W.	1901
Butement, Thomas, School of Mines, Kalgoorlie, W.A. ..	F.
Campbell, William Horace, c/o Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1920
Campion, G. W., 18 Carson road, Dulwich, S.E., London	1901
Carroll, John J., Kuaotunu, Auckland, N.Z.	1911
Chambers, Preston, 22 Shortland-street, Auckland, N.Z. ..	1912
§**Chapman, Professor R. W.**, The University, Adelaide, S.A.	1901
Chapple, Albert J. M., "Exeter," Barker-road, Strathfield, N.S.W.	1906
Chapple, William Henry Charles, Cobar Gold Mine, Cobar, N.S.W.	1921
Chomley, W. B., Zinc Corporation Ltd., Broken Hill, N.S.W.	1912
Church, Kenneth C., Broken Hill Pty. Ltd., Newcastle, N.S.W.	1913
Clark, Lindesay C., Derby, Tas.	1905
Clarke, Huntley J., Queenstown, Tas.	1901
Clayton, C. H. J., c/o Zinc Corporation Ltd., Broken Hill, N.S.W.	1913
Clayton, H. Edward, c/o Burma Mines Ltd., Bawdwin, via Namtu, Northern Shan States, Upper Burma ..	1920
§**Cleland, W. Lauder**, Broken Hill Pty. Ltd , Iron and Steel Works, Newcastle, N.S.W.	1907
§**Coldham, J. C.**, C.S.A. Mine, Cobar, N.S.W.	1907
Colley, Walter, c/o Messrs. Fearnley and Co., Cairns, Q. ..	1914
Conder, Hartwell, Strahan, Tas.	1915
Connor, J. D., 144 Barnard-street, North Adelaide, S.A. ..	1910
Conway, James, State Coal Mine, Bowen, Q.	1921
§**Corbould, W. H.**, c/o Australian Club, Sydney, N.S.W. ..	1908
§**Courtney, Charles Frederick**, Sulphide Corporation Ltd., 34 Queen street, Melbourne, Vic.	1901
§**Cowles, Richard K.**, New Sylvia G.M. Co., Box 55, P.O., Thames, N.Z.	1911
Crabb, Josiah, Inspector of Mines, Southern Cross, W.A. ..	1920
Cranz, William Nelson, Broken Hill Proprietary Ltd., Broken Hill, N.S.W.	1921
Crozier, Robert H., c/o Burma Mines Ltd., Namtu, Northern Shan States, Upper Burma	1909
Crutchett, Edgar A., Great Boulder G.M. Co., Boulder, W. A.	1909

Names and Addresses.	Date of Election.
Currie, David, 276 Salisbury House, London Wall, London, E.C. 2.	1911
Daggar, H. James, Queen's Bridge Square, South Melbourne, Vic.	1901
§Davies, H. Warlow, c/o Electrolytic Zinc Co. of Australasia Ltd., Risdon, Tas.	1910
Dawson, Edward H., 18 Exchange, Broken Hill, N.S.W.	1910
§Delprat, G. D., Broken Hill Pty. Ltd., Equitable Buildings, Melbourne, Vic.	1902
§Denny, G. A., 1 Finsbury Pavement House, London, E.C. 2	F.
Dey, George, Balmoral-road, Port Pirie, S.A.	1920
§Dibdin, T. R., Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1910
Dickson, Gordon F., London & Rhodesian Mining & Land Co., 5 Moorgate-street, London	1909
Dixon, Clement, Box 305, P.O., Bulawayo, Rhodesia, South Africa	1900
¶Dobbie, H. Campbell, Mergui, Burma, India	1911
Dods, Richard, Mount Lyell Mining and Railway Co., Queenstown, Tas.	1910
Donaldson, James, Box 272, P.O., Cairns, North Q.	1914
§Donaldson, Robert J., Sulphide Corporation Ltd., Cockle Creek, N.S.W.	1905
Donnelly, Alf., c/o Mrs. Patterson, Argent-street, Broken Hill, N.S.W.	F.
Doolette, Dorham L., Nat. Mut. Buildings, St. George's-terrace, Perth, W.A.	1909
Drage, James, Ivanhoe Gold Corporation, Boulder, W.A.	1909
§Driffield, E. Carus, Queenstown, Tas.	F.
Dubois, A. J., "Walhalla," Fernsplatt, Perranwell, S.O., Cornwall, England	1908
Dunn, A. C., Central Mine, Broken Hill, N.S.W.	1908
Dyason, Edward C., Equitable Building, Melbourne, Vic.	1906
§Dyson, Thomas Ingleby, c/o Australasian Institute of Mining and Metallurgy, 48 Queen-street, Melbourne, Vic.	F.
Eastaugh, Frederick A., University Club, Sydney, N.S.W.	1910
Eaton, J. Murdoch, Royalist Mine, Que Que, Rhodesia, South Africa	1905
§Edmands, H. R., Riverina South G. M. Co., Menzies, W.A.	1901

Names and Addresses.	Date of Election.
Edquist, Victor T., Youanmi Gold Mines Ltd., Youanme, W.A.	1909
Emery, Cyril J., British Mine, Broken Hill, N.S.W. ..	1919
Espie, Frank F., Burma Mines Ltd., Bawdwin, Upper Burma	1918
Evans, H. A., Sulphide Corporation Ltd., Boolaroo, N.S.W.	1911
Evans, James H., Gold and Scheelite Pty. Ltd., Golden Point, Macrae's Flat, Otago, N.Z...	F.
Ewart, John, North Broken Hill Mine, Broken Hill, N.S.W.	1910
§Fairweather, Andrew, Broken Hill South Mine, Broken Hill, N.S.W.	1912
Farrier, William Charles Valentine, P.O. Box 28, Broken Hill, N.S.W.	1913
Faul, Charles, "Moola," St. Leonard's-avenue, St. Kilda, Vic.	1910
Fisher, D. H., Mount Morgan, Q.	1907
Foster, Donald F., The Cliffe, Belmont, Sutton-Surrey, England	1913
Fraser, Alex., Great Boulder Pty. Ltd., Boulder, W.A ..	1909
Fraser, Colin, c/o Broken Hill Associated Smelters Ltd., Collins House, 360 Collins-street, Melbourne, Vic. ..	1911
Fraser, Donald Lovat, Rockhampton Club, Rockhampton, Q.	1910
§Fraser, S. E., Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1911
Fray, Percival Richard, McMahon-street, St. Arnaud, Vic.	1910
§Freeman, Charles Cuthbert, Zinc Corporation Ltd., Broken Hill, N.S.W.	1913
Gall, Wm. C., North Mine, Broken Hill, N.S.W.	1910
Garde, Henry Thomas, Broken Hill Proprietary Mine, Broken Hill, N.S.W.	1913
Gardner, W. E., Central Mine, Broken Hill, N.S.W. ..	1902
Garland, Charles L., 11 Moore-street, Sydney, N.S.W. ..	1898
§Gartrell, H. W., The University, Adelaide, S.A.	1910
Gepp, Herbert W., c/o Electrolytic Zinc Co. of Aust. Ltd., Collins House, 360 Collins-street, Melbourne, Vic.	1910
Gibson, Angus A., Mount Morgan, Q.	1910
§Gilmour, Jas. L., Waihi, N.Z.	1904
Godden, F. W. R., Hampton Properties Ltd., Block 50, Hampton Plains, W.A.	1911
Gosman, William Alexander, Queenstown, Tas.	1913
Graham, Alexander Robert, State Coal Mine, Wonthaggi, Vic.	1920

Names and Addresses.	Date of Election.
Gray, George J., Gt. Western Hotel, Cobar, N.S.W. ..	1912
Greig, E. H. c/o Burma Mines Ltd., Nam Tu, Northern Shan States, Burma	1916
Grierson, J. J., South Australian Cement Co., Brighton, Adelaide, S.A.	1911
Grigg, Joseph, "Marieville," Irwin-street, East Fremantle, W.A.	1920
§Gunn, Francis, Finnis-street, Gawler, S.A.	1910
Hack, Clem. A., 360 Collins-street, Melbourne, Vic. ..	1905
Haigh, Victor A., Broken Hill Proprietary Block 10 Ltd., Broken Hill, N.S.W.	1910
Hales, Robert G., Magnet, Tas.	1914
Hall, Ernest K., Junction North Mine, Broken Hill, N.S.W.	1920
§Hall, John F., 14 New Zealand Chambers, Queen-street, Brisbane, Q.	1918
Hamilton, Henry J. E., British Mine, North Broken Hill, N.S.W.	1910
§Hamilton, Richard, Great Boulder Pty. G.M. Co., Boulder, W.A.	1906
§Hancock, H. Lipson, Wallaroo, S.A.	F.
Hansen, L., Ajax North Mine, Daylesford, Vic.	1908
§Hanton, Thos. G., c/o Zinc Corporation Ltd., Broken Hill, N.S.W.	1919
Hargraves, E. P, c/o David & Toft, Singapore	1915
§Hart, G. Stephen, Commonwealth Cement Co., Portland, N.S.W.	1910
Hasson, Robt., Hagelthorne-street, Wonthaggi, Vic. ..	1915
Hay, Archibald L., Bullfinch Pty., Bullfinch, W.A. ..	1909
Hayes, William H., Moonta Mines, Moonta, S.A.	1910
§Hebbard, James, Central Mine, Broken Hill, N.S.W. ..	1902
Henderson, Edwin T., Broken Hill Pty. Ltd., Broken Hill, N.S.W.	1910
§Herman, Hyman, Mines Department, Treasury Buildings, Melbourne, Vic.	1897
Hetherington, J. W., M. L. A. Chambers, Queen-street, Brisbane, Q.	1911
Higgin, Alfred J., The University, Melbourne, Vic. ..	1912
Hills, Loftus, Geological Survey Office, Launceston, Tas. ..	1921
§Hitchcock, W. E., Bismuth, Tin and Wolfram Mine, Moina, near Wilmot, Tas.	1904

Names and Addresses.	Date of Election.
Hofman, Prof. H. O., Massachusetts Institute of Technology, Boston, Mass., U.S.A.	1914
Honman, C. Sidney, Greensborough, Vic.	1920
Horsburgh, James, Mount Morgan G.M. Co. Ltd., Mount Morgan, Q.	1908
§Horwood, E. J., c/o Broken Hill Pty. Ltd., Equitable Buildings, Melbourne, Vic.	1902
Hosking, Arthur F., P.O., Champion Reefs, Mysore State, India	1920
Howe, A. Maxwell, Department of Mines (State Batteries Branch), Perth, W.A.	1901
Hughes, Joseph Albert, School of Mines, Charters Towers, Q.	1911
Hunter, Peter, State Coal Mine, Wonthaggi, Vic.	1912
§ Hunter, Stanley B., Mines Department, Treasury Buildings, Melbourne, Vic.	1894
Hylton, C. G., Zinc Corporation Ltd., Broken Hill, N.S.W.	1906
Ikeda, Kenzo, c/o Fujita & Co., Dojima, Osaka, Japan	1918
Imanaga, T., Müke, Japan	1917
Ireland, Mark, South Cameron, Tas.	1902
§ Jakins, G. Fred., North Lyell, Tas.	1910
James, Eric L., P.O., Lake Boga, Vic.	1910
James, John C., "Boomerah," Wetherall-street, Croydon, Sydney, N.S.W.	1913
§Jarman, Arthur, 1001 Spruce-street, Berkeley, Cal., U.S.A.	1910
§Jensen, E. Broughton, "Cimbria," East Terrace, Adelaide, S.A.	1909
§ Jensen, William S., Mount Morgan G.M. Co. Ltd., Mount Morgan, Q.	1908
§ Johns, Frederick C., c/o Junction North Mine, Broken Hill, N.S W.	1911
Johns, Morgan J., Mount Morgan G.M. Co. Ltd., Mount Morgan, Q.	1909
§Johnston, W. H., Waihi, N.Z.	1904
Joice, John, c/o Raub Australian G.M. Co. Ltd., Raub, Pahang, Fed. Malay States	1918
§ Jones, David, Waratah, Tas.	F.
Jones, Henry, Inspector of Mines, Kadina, S.A.	1910
Judge, James, Ravenswood, North Q.	1911
Julius, Archibald C., Ottery Mine, Tent Hill, N.S.W.	1919

Names and Addresses.	Date of Election.
§Kenyon, A. S., State Rivers and Water Supply Commission, Treasury Gardens, Melbourne, Vic.	1896
Key, John F., British Mine, Broken Hill, N.S.W.	1912
King, A. J., c/o A. W. Freeman, Taiping, Perak, Fed. Malay States	1911
King, E. M., "Leura," Launceston, Tas.	F.
Kingston, Wm., School of Mines, Bairnsdale, Vic.	1914
§Kitson, Albert E., 109 Worple-road, Wimbledon, Surrey, England	1904
Klug, Geo. C., c/o Bewick, Moreing and Co., 360 Collins-street, Melbourne, Vic.	1909
Ladd, David H., 8th Floor, Barnes Buildings, Muskogee, Oklahoma, U.S.A.	1911
Lakeland, William J., "Moreland," Ballarat East, Vic. ..	1913
§Larcombe, C. O. G., School of Mines, Kalgoorlie, W.A. ..	1908
Laun, Ernest J., Inspector of Mines, Charters Towers, Q...	1909
§Lavers, Herbert, Block 14 Mine, Broken Hill, N.S.W. ..	1910
Learmont, Tom, Broadway, Reefton, N.Z.	1911
Leggo, A. Victor, Metallurgical Works, Bendigo, Vic. ..	1908
Leggo, H. M., Mount Korrong-road, Job's Gully, Bendigo, Vic.	1901
Leitch, Walter, Blackball, N.Z.	1911
Lester, Thomas, Mount Morgan Extension Co. Ltd., Mount Morgan, Q.	1911
Lewis, Essington, Broken Hill Pty. Ltd., Equitable Building, Melbourne, Vic.	1918
§Lewis, James B., 31 Queen-street, Melbourne, Vic. ..	1906
Lidgey, Cecil R., G. H. & Co., Vickery's Chambers, 76 Pitt-street, Sydney, N.S.W.	1911
Lilburne, Albert S., Raub Australian G.M. Co., Raub, Pahang, Fed. Malay States	1911
Lindsay, John A., Broken Hill, N.S.W.	1906
Lockyer, Ormonde H. S., Edwards Metallurgical Works, Sebastopol, Ballarat, Vic.	1910
Loring, W. J., 62 London Wall, London, E.C.2. ..	1909
§Low, V. F. Stanley, c/o National Bank of Australasia, 5 Bishopsgate, London, E.C.	1902
Lund, Jens, 64 Clyde-road, Addiscombe, Surrey, England ..	1902
Macartney, E. H. B., Perth, W.A.	1901

Names and Addresses.	Date of Election.
Mackay, Alexander D., Batman House, 103 William-street, Melbourne, Vic.	1913
Mackenzie, D. C., "Æneas," Burns-street, St. Kilda, Vic. ..	1910
Macleod, Peter J., The University, Hobart, Tas. ..	1901
Macnicol, A. N., 31 Queen-street, Melbourne, Vic. ..	1906
M'Bride, Wm. J., Broken Hill South Ltd., Broken Hill, N.S.W.	1920
M'Conachie, Wm., Waihi Grand Junction Co., Waihi, N.Z. ..	1910
M'Cormick, W. J., Broad-street, Thames, N.Z.	1912
M'Geachie, Duncan, Caledonian Collieries Ltd., Newcastle, N.S.W.	1912
M'Geachie, John, Hillton Cottage, West Wallsend, N.S.W.	1908
M'Keown, Maurice R., Vegetable Creek Tin Mine, Emmaville, N.S.W.	1912
§M'Leish, John, State Coal Mine, Wonthaggi, Vic. ..	1912
M'Padden, John F., School of Mines, Westport, N.Z. ..	1911
Marryat, Cyril B., National Physical Laboratory, Teddington, Middlesex, England	1910
Mars, F. J., Broken Hill South Mine Ltd, Broken Hill, N.S.W.	1902
Marshall, Reginald R., Central Mine, Broken Hill, N.S.W.	1910
Martin, Edward, Shire Hall, Bright, Vic.	1902
§Mathers, J. V. W., Mararoa Gold Mining Co., Light of Asia Mine, Cue, W.A.	1914
§Matheson, Alex. M., Waratah, Tas.	1913
§Matters, Clem. W., High-street, Unley Park, Adelaide, S.A.	1910
§Mawdsley, W. H., P.C., Rockhampton, Q.	1898
Meredith, David, Electrolytic Zinc Co. of Australasia Ltd., Risdon, Tas.	1910
Merrill, Chas. W., Room 502, 121 Second-street, San Francisco, Cal., U.S.A.	1908
Merrin, Arthur H., Mines Department, Treasury Buildings, Melbourne, Vic.	1903
Messenger, William T., Zinc Corporation Ltd., Broken Hill, N.S.W.	1913
Miller, Joseph, Story's Creek Tin Mining Syndicate, Avoca, Tas.	1920
Mitchell, John P., Atlas Buildings, 8 Spring-street, Sydney, N.S.W.	1909
§Mitchell, S. R., Burnley-street, Richmond, Vic. ..	1912
Moen, Oluf, P.O., Riverton, Southland, N.Z.	1911

Names and Addresses.	Date of Election.
Moline, Arthur H. P., Bendigo Amalgamated Goldfields, N.L., Bendigo, Vic.	1909
Molineaux, Herbert S., The Reefs, Central Otago, N.Z.	1911
Moncrieff, P. W., Zinc Corporation Ltd., Broken Hill, N.S.W.	1919
§Montgomery, A., Department of Mines, Perth, W.A.	F.
Moore, Karl Byron, Electrolytic Zinc Co. of Australasia, Risdon, Tas.	1913
Moore, Robert M‘I., Macquarie-street, Dubbo, N.S.W.	1912
More, George A., c/o Sime, Darby and Co. Ltd., Singapore	1921
§Morgan, Percy G., Geological Survey Office, Wellington, N.Z.	1900
Morison, David N., Newcastle, N.S.W.	1920
Morse, Phillip S., 157 Walnut-street, Brooklyn, Mass., U S.A.	1905
Morse, Willard S., Seaford, Delaware, U.S.A.	1901
§Moss, Frank A., Dalgety Buildings, William-street, Perth, W.A.	F.
Moulden, J. C., Central Zinc Co., Seaton-Carew, near Middlesborough, England	1906
Moule, John W., Burma Mines Ltd., Bawdwin, Upper Burma	1908
Moxon, Claude H. Hercules Gold and Silver Mining Co, Williamsford, Tas.	1915
Mulligan, Edric N., University Club, Castlereagh-street, Sydney, N.S.W.	1910
Mulligan, W. J., Grafton Copper Mines, Cangai, N.S.W.	1910
Murdoch, Fredk. M., Waterloo Chemical Works, 173a Botany-road, Waterloo, N.S.W.	1915
Murphy, Frank, Great Cobar Ltd., Cobar, N.S.W.	1912
Murray, Geo. D., Ivanhoe Gold Corporation Ltd., Boulder, W.A.	1909
§Murray, Russell M., Mount Lyell Mine, Gormanston, Tas.	1911
Murray, Virginius H. R., Golden Horseshoe Estates Co., P.O. Box 78, Boulder, W.A.	1909
Nakamura, Keijiro, Baron Sumitomo's General Head Office, Kitahama, Osaka, Japan	1914
§Newman, J. Malcolm, Pratten Buildings, 26 Jamieson-street, Sydney, N.S.W.	1910
Nicol, W. J., "Dieppe," Alexandra, Vic.	1910
Nicholson, L'Estrange, Mount Elliott Mine, Selwyn, Q.	1913

Names and Addresses.	Date of Election.
Noble, Jas. R., Muir's Gold Reefs Ltd., Te Puke, Bay of Plenty, N.Z.	1910
O'Brien, Edward, c/o Broken Hill Pty. Ltd., Box 196, Newcastle, N.S.W.	1910
O'Brien, Kirk, 360 Collins-street, Melbourne, Vic.	1911
Osborne, Percy R., Port Moresby, Papua	1921
Owen, T. Mackellar, 116, 118 Clarence-street, Sydney, N.S.W.	1914
§Palmer, Thos. H., Collins House, 360 Collins-street, Melbourne, Vic.	1910
Parsonage, William, State Coal Mine, Runanga, Greymouth, N.Z.	1920
§Patterson, B. G., Mount Morgan, Q.	1907
Paul, Matthew, Inspector of Mines, Waihi, N.Z.	1910
§Paull, W. J., "Codrington," Bowenville, Darling Downs, Q.	F.
Payne, Professor Henry, The University, Melbourne, Vic.	1911
§Pearce, W. C. Walworth, Lancelot, via Herberton, Q.	1906
Pearson, J. L., Wallaroo Mines, S.A.	1913
Peberdy, James R., c/o Australasian Institute of Mining and Metallurgy, 48 Queen-street, Melbourne, Vic.	1910
Penman, Arthur Percy, City Bank Chambers, Newcastle, N.S.W.	1911
Pomroy, H., Wallaroo Mines, S.A.	1913
§ Poole, Wm. (Julius & Poole), Culwulla Chambers, Castlereagh-street, Sydney, N.S.W.	1905
§Pound, J. R., School of Mines, Ballarat, Vic.	1920
§Power, F. Danvers, Perpetual Trustees Chambers, 33-39 Hunter-street, Sydney, N.S.W.	F.
Rae, Cecil, Ipoh, Perak, Fed. Malay States	1908
Read, Thomas A., "Warrawee," Thomas-street, Broken Hill, N.S.W.	1918
Reid, A. M'Intosh, Geological Survey Offices, Launceston, Tas.	1919
Reid, Major D. E., Gympie, Q.	1910
Rhodes, Charles, Ronaki, Remuera, Auckland, N.Z.	1911
§Rhodes, Fred. N., c/o Wilson's (N.Z.) Portland Cement Co. Ltd., Portland, N.Z.	1910
Ridge, H. M., 2 Gt. Winchester-street, London, E.C.	1901
Rickleman, H., c/o Electrolytic Refining Co., Port Kembla, N.S.W.	1907
§Rigby, Edward J., 482 Collins-street, Melbourne, Vic.	F.

Names and Addresses.	Date of Election.
Rigg, Gilbert, Broken Hill Associated Smelters Ltd., 360 Collins-street, Melbourne, Vic.	1917
Roberts, Geo. M., Associated Northern Blocks (W.A.) Ltd., Kalgoorlie, W.A.	1909
§ Roberts, Nicholas J., Central Mine, Broken Hill, N.S.W. ..	1913
Rodda, E. J. J., "Ensanada," Murdock-street, Cremorne, Sydney, N.S.W.	1907
Rodda, Stanley N., Melbourne Technical College, Melbourne, Vic.	1910
Rolfe, R. A., 53 West-street, North Sydney, N.S.W. ..	1915
Rose, Walter J., Electrolytic Zinc Co. of Australasia Ltd., 360 Collins-street, Melbourne, Vic.	1909
Rowe, F. Walton, Oroya Links Ltd., Kalgoorlie, W.A. ..	1913
Rusha, Richard A., Abu Tin Mining Co. Ltd., via Jemaa, Narrarawa Province, Northern Nigeria, West Africa ..	1912
Russell, Murray, Inspector of Mines, c/o Dept. of Mines, Brisbane, Q.	1912
Ryan, Cecil G., Bradshaw's Creek, Tas.	1908
Sander, George E., Rhodesian Lead and Zinc Syndicate Ltd., Broken Hill, Rhodesia, South Africa	1910
§Sarvaas, Johan, Melbourne Technical College, Melbourne, Vic.	1902
Saunders, George J., Technical College, Ipswich, Q. ..	1904
Savage, A. E., "Nangeela," Point-road, Woolwich, Sydney, N.S.W.	1911
Schlapp, H. H., Collins House, 360 Collins-street, Melbourne, Vic.	F.
Scoble, E. J., Adams-street, Waihi, N.Z.	1917
Scott, James Balfour, Renison Bell, Tas.	1913
Scott, Malcolm B., c/o Mrs. Duff, Commercial-road, Hobart, Tas.	1909
Shaw, J. B., c/o Union Bank of Australia Ltd., Pitt-street, Sydney, N.S.W.	1910
Shepherd, H. Frank, Hauraki Mines, Coromandel, N.Z. ..	1911
¶§ Skeats, Professor E. W., The University, Melbourne, Vic.	1905
§Slee, Richard T., Broken Hill Pty. Ltd., Broken Hill, N.S.W.	1902
§Slessor, Robt., Arnhold Bros. and Co., Changsha, Hunan Province, China	1905
Smith, A. Mica, School of Mines, Ballarat, Vic.	1906
Smith, C. E. Kennedy, State Battery, Ora Banda, W.A. ..	1912

Names and Addresses.	Date of Election.
Smith, C. Lonsdale, "Darnick," Larkin-street, Bay-road, Sydney, N.S.W.	1905
§Smith, F. Voss, Block 14 Co., Broken Hill, N.S.W.	1909
Smith, J. D. Audley, Box 1557, P.O., Sydney, N.S.W.	.1910
Somerset, H. St. J. (jun.), Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1898
Speight, Robert, Canterbury Museum, Christchurch, N.Z.	1911
Stephen, J. Farish, "Rydalmount," Webb's-avenue, Ashfield, Sydney, N.S.W.	1918
Stephenson, Clement T., 39 Wrixon-street, East Kew, Vic.	1912
Stewart, Farquhar, Walsh-street, Reefton, Westland, N.Z.	1910
¶§Stewart, Hector, "Solai," Wagin, W.A.	1902
§Sticht, Robert C., Mount Lyell Mining and Railway Co. Ltd., Queenstown, Tas.	1901
Stillwell, Frank Leslie, c/o Bendigo Amalgamated Goldfields, N.L., Bendigo, Vic.	1921
Stirling, J., Burnie, Tas.	F.
Stokes, C. H., "Thornville," Kerr-street, Mayfield, Newcastle, N.S.W.	1910
Stokes, Reginald H., "Labrena," Beaconsfield-road, Mosman, N.S.W.	1911
Stutterd, Louis N., Post-office, Port Darwin, Northern Territory	1913
Süssmilch, C. A., Technical College, Newcastle. N.S.W.	1904
Sutherland, John W., Golden Horseshoe Estates Ltd., Boulder. W.A.	1909
Sutherland, Wm. G., Smelting Works, Fremantle. W.A.	1909
Taylor, E. Hogan, "Wyuna," 30 Carlisle-street, St. Kilda, Vic.	1913
Thomas, Harry A., Carisbrook. Vic.	1910
Townsend, C. T., Cyanide Works, One-Mile, Gympie, Q.	1908
Trenerry, Edward, Moonta Mines, S.A.	1911
Turnbull, T. A., 156 Hardy-street, Nelson, N.Z.	F.
Turner, A. D., Falcon Mines Ltd., via Umvuma, Rhodesia, South Africa	1913
§Turri, G. G., The Rialto, Collins-street, Melbourne, Vic.	F.
Ullman, A. T., Clarendon Hotel, Hunter-street, Newcastle, N.S.W.	1914
Ulrich, Gerard A., c/o Inst. of Mining and Metallurgy, Salisbury House, 1 Finbury Circus, London, E.C. 2	1911

Names and Addresses.	Date of Election.
Waddell, W. A., Koorboora, via Cairns, Q.	F.
§Wainwright, W. E., Broken Hill South Ltd., 360 Collins-street, Melbourne, Vic.	1902
§Wallmann, H. P., 26 Vautier-street, Elwood, Vic.	1910
Walls, Goiders, Devonport West, Tas.	1920
Walsh, Peter J., c/o Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1920
Walton, Robert W., 324 Bondi-road, Bondi, N.S.W.	1911
Ward, L. Keith, Director of Mines, Department of Mines, Adelaide, S.A.	1918
§Waterhouse, Leslie V., c/o Mount Hope Ltd., Mount Hope, N.S.W.	1910
§Waters, Professor D. B., The University, Dunedin, N.Z.	1904
Watson, James T., Chillagoe Ltd., Mt. Mulligan, via Cairns, Q.	1911
Wauchope, A., Johnstone-street, Cottesloe, W A.	1909
Weigall, A. R., c/o Seoul Mining Co., Suan Mine, Hol Kol, Whang Hai Province, Korea	1910
Weigall, H. S., Taio G.M. Co. Ltd., Nakatsue Mura, Hida Gun, Oita Ken, Kyushu, Japan	1912
Weinberg, E. A., 25 Broad-street, New York, U.S.A.	F.
Weir, George, 360 Collins-street, Melbourne, Vic.	1902
Westcott, L. A., "Catumnal," Corfield, Q.N.R., Q.	1907
§White, Edmond A., Electrolytic Refining Co., Port Kembla, N.S.W.	1900
White, Francis P., Goonengerry, via Mullunbimby, North Coast, N.S.W.	1913
§White, Norman F., "Warrandaroo," Longerock, Q.	1899
Whitfeld, H. E., The University, Perth, W.A.	1914
Whitley, Alexander, Inspector of Mines, Dunedin, N.Z.	1911
Wilkins, Laurence G., Broken Hill Proprietary Ltd., Newcastle, N.S.W.	1913
§Williams, Luke, "Claremont," Moonah, Tas.	1894
§Williams, Owen B., c/o North Mount Farrell Co., N.L., Tullah, Tas.	1910
Williams, Thomas H., Leonora G. Blocks, Leonora, W.A.	1910
Wilson, A. Laurence, New Ravenswood Ltd , Ravenswood, Q.	1909
Wilson, Douglas de C., Junction North Mine, Broken Hill, N.S.W.	1920
Wilson, F. G., Y-Water Tin Co., N.L., Emmaville, N.S.W.	1910
Wilson, Harry, 31 Queen-street, Melbourne, Vic.	1914

Names and Addresses.	Date of Election
Wilson, William T. S., Extraction Works, Pæroa, Auckland. N.Z.	1911
Winter, Arthur S., C.S.A. Mines Ltd., Cobar, N.S.W.	1918
§Wood, James P., School of Mines, Adelaide, S.A.	1910
§Woodward, Oliver H., Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1912
Worsley, Henry E., Broken Hill Pty. Ltd., Broken Hill, N.S.W.	1910
§Wright, Geo. W., Mt. Lyell Mining and Railway Co. Ltd., Queenstown, Tas.	1906
§Wylie, Wm., Tingha, via Guyra, N.S.W.	F.
Young, Gerald W., "Rona," Toorak-road, Toorak, Vic.	1909

ASSOCIATE MEMBERS.

Adcock, Garnet I., Viticultural College, Rutherglen, Vic.	1911
Alford, L. C., "Oakhampton," Wellington. N.Z.	1910
Anderson, A. F. S., c/o Tongkah Harbour Tin Dredging Co., Puket, West Siam, via Penang	1914
Anderson, William T., "Clifton," Ben Boyd-road, Neutral Bay, N.S.W.	1910
Atkinson, J., Emmaville, N.S.W.	1907
Baldwin, Percy H., Mount Morgan, Q.	1910
Banks, John H. G., Waihi G.M. Co., Waihi, N.Z.	1910
Barclay, Fred. E., "Burra Bra," Thinkoswald Avenue, Mosman, Sydney, N.S.W.	1912
Barker, Nigel Chase, Atlas Buildings, Spring street, Sydney, N.S.W.	1911
Barkley, Ernest, Mount Lyell Mining and Railway Co. Ltd., Gormanston. Tas.	1906
Beckwith, Ralf N., c/o Sulphide Corporation Ltd., Port Pirie, S.A.	1910
Berriman, Ralph V., "Bolton," 18 Daphne-street, Prospect, S.A.	1920
Black, Arnold B., 8 Zebina-street, Broken Hill, N.S.W.	1912
Boyd, Eric Ewart Gladstone, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.	1921
Boydell, W. G. B., c/o Seoul Mining Co., Hol Kol Mine, Whang Hai Province, Chosen, Korea	1911

Names and Addresses.	Date of Election.
Broad, Wilfred Ray, c/o British Broken Hill Proprietary Co., Broken Hill, N.S.W.	1920
Brown, G. Twentyman, "Glenfern," Mathoura-road, Toorak, Vic.	1910
Bullen, G. L., Block 14 Torrington, Bismuth, via Deepwater, N.S.W.	1913
§Burbidge, Percy, Mount Elliott Mine, Selwyn, North Q.	1910
Caithness, W. R., c/o Fraser and Chalmers Ltd., 257 Clarence-street, Sydney, N.S.W.	1909
Campbell, A. G., c/o Burma Mines Ltd., Namtu, Northern Shan States, Upper Burma	1911
Campbell, J. K., Stannary Hills, via Cairns, Q.	1915
Carless, Noel, Walney House, Waihi, N.Z.	1913
Carroll, Hubert H., c/o Broken Hill South Ltd., Broken Hill, N.S.W.	1920
Casey, Richard G., 125 William-street, Melbourne, Vic.	1909
Christian, Arthur J., The Ranch, Oxide-street, Broken Hill, N.S.W.	1910
Clapp, L. P., 76 Chloride-street, Broken Hill, N.S.W.	1910
Clark, Archie S., c/o Amalgamated Zinc (De Bavay's) Ltd., Broken Hill, N.S.W.	1910
Cole, William H., Waihi Grand Junction Ltd., Waihi, N.Z.	1912
Collison, Arthur G., King William-street, Adelaide, S.A.	1902
Cooke, Herbert R., N.Z. Express Coy's. Building, No. 12 Fort-street, Auckland, N.Z.	1911
Corstophan, V. A., c/o Electrolytic Zinc Co. of Australasia Ltd., Risdon, Tas.	1915
Court, A. Lacy, c/o Central Mine, Broken Hill, N.S.W.	1913
§Courtney, Guy, c/o Sulphide Corporation Ltd., Boolaroo, N.S.W.	1912
Crace, Melville C., Broken Hill South Ltd., Broken Hill, N.S.W.	1911
Craig, J. H., Albion Chambers, Bendigo, Vic.	1911
Cribb, H. B., Lower Quarters, Mount Morgan, Q.	1910
Cumming, Alex., Irvinebank Co., Irvinebank, North Q.	1911
Danks, Aaron T., 391 Bourke-street, Melbourne, Vic.	1905
Ditchburn, Gordon L. A., c/o Yukon Dredging Co., 16 Loke Yew Buildings, Kuala Lumpur, Fed. Malay States	1910
Dod, H. Charlton, S.A. Oil Wells Co., Tantanoola, S.A.	1914

Names and Addresses.	Date of Election.
§Dow, Edmund B., c/o Sulphide Corporation Ltd., Boolaroo. N.S.W.	1910
Dow, John, Golden Horseshoe Estates Ltd., Boulder, W.A.	1910
§Drain, Percy J., "Kingsley," Kitchener-road, Artarmon, Sydney, N.S.W.	1910
Dunn, John A., c/o Imperial College of Science and Technology, South Kensington, London, S.W. 7	1921
Dunstan, Basil G., c/o Australian Slate Quarries, Willunga, S.A.	1911
§Edwards, Ed., "Glenesk," Callintina-road, Hawthorn, Vic.	1907
Elford, Chas., P.O. Box No. 11, Chillagoe, North Q. ..	1910
Fisher, W. Hamilton, 46 Ward-street, Kalgoorlie, W.A. ..	1913
Flockart, Colin P., 53 Broadway, East Camberwell, Vic.	1912
Fox, James Michael, North Mine, Broken Hill, N.S.W. ..	1910
§Foxall, John S., Sons of Gwalia Mine, Gwalia, W.A. ..	1912
Fry, Arthur E., c/o Zinc Corporation Ltd., Broken Hill, N.S.W.	1919
§Fry, Sidney, Reefton, N.Z.	1907
Gabriel, G. Escott, 327 Bromide-street, Broken Hill, N.S.W.	1920
Game, George B., South Silver Mine, Broken Hill, N.S.W.	1918
Garnett, Robert K., 554 Chapple-street, Broken Hill, N.S.W.	1920
Gluyas, B. C., Broken Hill Pty. Ltd., Newcastle, N.S.W.	1913
Gray, William, Anglo-Persian Oil Co. Ltd., c/o Whitten Bros., Port Moresby, Papua .. .: ..	1921
Greening, Walter, Te Aroha, N.Z.	1911
Greenlees, Alan D. Amalgamated Zinc (De Bavay's) Ltd., Broken Hill, N.S.W.	1910
Grieve, William H., c/o William Adams and Co., 175 Clarence-street, Sydney, N.S.W.	1911
Grosse, William J., 63 Patton-street, South Broken Hill, N.S.W.	1913
Guppy, Clarence H. R., Nowra, N.S.W.	1911
Hart, William, Mount Lyell Mining and Railway Co. Ltd., Gormanstown, Tas.	1913
Harvey, Phillip, School of Mines, Charters Towers, Q. ..	1910
Heycock, C. R., Moretown, Wairio, Southland, N.Z. ..	1914
Holder, Evan M., Central Mine. Broken Hill, N.S.W. ..	1910
Hooke, Arthur W., Forum River (Nigeria) Tin Co. Ltd., Naraguta, Northern Nigeria, West Africa	1911

Names and Addresses.	Date of Election.
Hookings, Herbert J., Assay Office, Broken Hill Pty. Ltd., Broken Hill, N.S.W.	1911
Hooper, Francis H., Block 14 Mine, Broken Hill, N.S.W.	1911
Hooper, Thomas H., Butlers Tin Mine, Torrington, N.S.W.	1919
§Hope, G. B., "Carrical." Hermitage-rd., Newtown, Geelong, Vic.	1911
Horsburgh W. W., Hampden-Cloncurry Copper Mines Ltd., Kuridala, North Q.	1911
Hunter, George M'I., c/o Electrolytic Zinc Co. of Australasia Ltd., Risdon, Tas.	1910
Irvine, C. L., c/o R. M. Clifton, 209 Townshend-road, Subiaco, W.A.	1913
Jones, Vincent N., Noosa Shire Council, Pomona, Q.	1910
§Junner, Norman R., c/o Gold Coast Geological Survey, Colonial Office, Downing-street, Westminster, London	1920
Klem, Leslie G., Noumea, New Caledonia	1919
Langford, Walter G., Vailala Oil Fields, Papua	1915
Lawn, Charles H., P.O. Box 85, Taranaki, N.Z.	1911
Leevers, William T, Great Boulder Perseverance G.M. Co., Fimiston, W.A.	1910
Le Souef, Sebert G., "Brockley," Wrexham-road, Windsor, Vic.	1910
Lewis, K. B., "Remo," 41 Kooyong-road, Armadale, Vic.	1915
Linz, Carl J., c/o Electrolytic Zinc Co. of Australasia Ltd., Risdon, Tas.	1920
§MacGruer, D. C., Sulphide Corporation Ltd., Boolaroo, N.S.W.	1915
M'Callum, N. S. Kellie, The Edith Mining Co. Ltd., Deepwater, N.S.W.	1911
McKay, James, Box 55, P.O., Greymouth, N.Z.	1911
Montgomery, John N., Upoia, Papua	1914
§Moore, Malcolm S., 31 Queen-street, Melbourne, Vic.	1912
§Morgan, R. J., Spassky, Zavod, Akmolinsk, Siberia	1911
Morris, A. C., Zinc Corporation Ltd., Broken Hill, N.S.W.	1913
§Nevett, Ralph D., Thomas-lane, off Chloride-street, Broken Hill, N.S.W.	1912
Newbigin, William J., c/o William Adams and Co., 521, 523 Collins-street, Melbourne, Vic.	1913
Nicholas, Frank H., c/o Burma Mines Ltd., Namtu, Northern Shan States, Burma, India	1913
Noall, John, c/o Pahang Consolidated Co. Ltd., Sungei Lembing, Kuantan, Singapore, Fed. Malay States	1921

Names and Addresses.	Date of Election.
Oliver, Robert Bruce, Tramway Terrace, Beryl-street, Broken Hill, N.S.W.	1919
Osborne, George W., Meekatharra, W.A.	1913
§Ower, Leslie H., c/o Miss I. Ower, 56 Esplanade, Brighton Beach, Vic.	1910
Patterson, R. H., Broken Hill Club, Broken Hill, N.S.W.	1912
Pearson, H. F., c/o Zinc Corporation Ltd., Broken Hill, N.S.W.	1912
Pethebridge, Harry Vernon, Main-road, Moonah, Hobart, Tas.	1915
Rabling, H., St. Joseph's Lead Mine, Bonne Terre, Missouri, U.S.A.	1914
Ramsden, Frederick Valentine, c/o J. W. Dudgeon, Scottish House, William-street, Melbourne, Vic. ..	1921
Rain, Allan D. M., Braden Copper Mines, Rancagua, Chili, South America	1911
Reid, G. D., Grantville, Vic.	1916
Robertson, Hubert James, Junction North Mine, Broken Hill, N.S.W.	1920
Robson, H. Carmichael, "Silverdale," Penzance, Cornwall, England	1913
Rogers, George, c/o Burma Mines Ltd., Namtu, Northern Shan States, Burma	1913
Ross, C. N., c/o The University of Queensland, Brisbane, Q.	1907
Rufus, Frederick Albert, Block 10 Mine, Broken Hill, N.S.W.	1920
Rutherford, Alex. R., Globe Mine, Reefton, N.Z. ..	1913
Rutherford, T. Wyville L., Consolidated Goldfields, Reefton, N.Z.	1913
Rutter, Hubert, "Yarra Braes," Eltham, Vic.	1908
Ryan, Denis L., Fremantle Trading Co., Fremantle, W.A. ..	1917
Salter, John W., 144 William-street, Broken Hill, N.S.W. ..	1912
Sampson, Thomas, c/o Benson Bros., Liverpool-street, Sydney, N.S.W.	1919
Seale, Harry V., Junction North Mine, Broken Hill, N.S.W.	1910
§Sewell, Robert M., School of Mines & Industries, Stawell, Vic.	1913
Shaw, John F., Block 14 Mine, Broken Hill, N.S.W. ..	1912
§Shellshear, Wilton, c/o Miami Copper Co., Miami, Arizona, U.S.A.	1910
Simpson, James, Crown Law Dept., Perth, W.A.	1910

Names and Addresses.	Date of Election
Skerritt, Alfred W., Kapsan Mines, Korea	1907
Sligo, A. D., Zeehan, Tas.	1911
Smith, H. Hardy, "Cora Lynn," Woolwich, Sydney, N.S.W.	1910
Smith, R. D., Hampden-Cloncurry Copper Mines Ltd., Trekelano, via Duchess, Cloncurry, Q.	1908
Smith, Walter G. A., 102 King-street, St. Peters, Sydney, N.S.W.	1912
Stanger-Leathes, A. C., 14 MacArthur-street, Ballarat, Vic.	1912
Stephen, Fenton W., Broken Hill Pty. Co., Broken Hill, N.S.W.	1910
Stephenson, Godfrey, Mount Hope, N.S.W.	1917
Stephenson, Herbert, "Beaumaris," Fletcher-street, Bondi, Sydney, N.S.W.	1910
Stichnoth, Ludwig F., Box 47, P.O., Mt. Morgan, Q. ..	1910
Swan, Arthur Howard, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.	1920
Sweet, Oswald G., South Extended Mine, Broken Hill, N.S.W.	1910
Thomas, Frank N., South Mine, Broken Hill, N.S.W. ..	1911
Thompson, Charles G. L., c/o New Guinea Copper Mines Ltd., Port Moresby, Papua	1921
Thomson, F. D., c/o W. S. Gibson, 40 Young-street, Albert Park, Vic.	1908
Topp, A. A., 12 Cromwell road, Hawksburn, Vic.	1909
Townsend, Harold, "The Wurlie," Iodide-street, Broken Hill, N.S.W.	1910
Treloar, Fred. L., Oxide-street, off Morgan-lane, Broken Hill, N.S.W.	1913
Twine, George J., Queensland Cement and Lime Co., Darra, Q.	1914
Vaughan, Rupert M., Milton Bryan Rectory, Woburn, Beds., England	1911
Waine, Victor J., Colonial Sugar Refining Co., Sigatoka, via Lantoka, Fiji	1908
§Warren, P. Hampton, Broken Hill South Mine, Broken Hill, N.S.W.	1910
§Watkins, Augustus E., St. Aubyn-street, New Plymouth, Taranaki, N.Z.	1911
Watson, Herbert, c/o Amalgamated Zinc (De Bavay's) Ltd., Broken Hill, N.S.W.	1911

Names and Addresses.	Date of Election.
White, Fredk. G. (White & Hosier), Broken Hill, N.S.W.	1911
Whitehead, Edwin A., "Alallaba," 6 North Terrace, Kensington Gardens, S.A.	1902
Whiteman, Woodleigh D., British Mine, Broken Hill, N.S.W.	1913
Whitington, Bertram., Mt. Lyell School of Mines, Queenstown, Tas.	1915
Williams, Arthur, Oxide Creek Ltd., Mt. Gordon Mine, via Cloncurry, Q.	1915
Williams, Oswald M., Inspector of Mines, Mareeba, Nth. Q.	1919
Williams, W. Ewart, Block 10 Mine, Broken Hill, N.S.W.	1912
Williamson, Milton Arthur, "The Ranch," Oxide-street, Broken Hill, N.S.W.	1920
Wilson, Wilfred A., Lakes Creek, Q.	1911
Winters, R. J., c/o Government Geologist, Entebbe, Uganda, British East Africa	1914
Zeugofsge, F. C., 288 Patton-street, South Broken Hill, N.S.W.	1910

STUDENTS.

Alexander, Hubert, Black Range West G.M. Co., Sandstone, W.A.	1912
Anderson, Archibald G., "Leacroft," Parnell Place, E. Newcastle, N.S.W.	1913
Anderson, E. S., c/o R. E. Chapman, Bank of New South Wales, Ballarat, Vic.	1912
Barson, Thomas L., Railway Town, Broken Hill, N.S.W.	1913
Bloom, Leo, Merivale-street, South Brisbane, Q.	1913
Blunden, Leslie E., 228 Elizabeth-street, Brisbane, Q.	1910
Burns, Felix G., Terminus Hotel, Williamsford, Tas.	1914
Colman, Wm. R. G., Upper Sturt, S.A.	1920
Combe, A. D., c/o Government Geogolist, Entebbe, Uganda, British East Africa	1912
Corrie, Colin C., Electrolytic Zinc Co. of Australasia Ltd., 360 Collins-street, Melbourne	1911
Crawford, H., School of Mines, Thames, N.Z.	1912
Cropp, Walter H. J., 65 Filleul-street, Dunedin, N.Z.	1920

Names and Addresses	Date of Election.
Dale, Roger T. H., 47 Harrington-street, Port Chalmers, N.Z.	1920
Dean, Harry M., School of Mines, Charters Towers, Q. ..	1911
Fabrikant, I. B., 50 Erskine-street, North Melbourne, Vic.	1915
Fraser, Ernest H., Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1911
Gibbons, Leo P. J., W.A. School of Mines, Kalgoorlie, W.A.	1920
Goode, Kenneth B., c/o Matthew Goode and Co., 18 Silk-street, London, E.C.2	1913
Green, Harold Litchfield, c/o W. Green, Union S.S. Co. (N.Z.) Ltd., Dunedin, N.Z.	1920
Hill, James, Box 27, P.O., Many Peaks, Q.	1907
Hopkins, John, c/o Broken Hill Associated Smelters Ltd., Port Pirie, S.A.	1920
Horsley, Ralf D., Stannary Hills, North Q.	1910
Hughes, Eric W., School of Mines, Adelaide, S.A. ..	1913
Kelly, A. H., Croas-street, Mayfield, N.S.W.	1913
Kelly, Monckton B. H., 60 Queen-street, Melbourne, Vic.	1913
Kerr, Frederick T., c/o Central Mine, Broken Hill, N.S.W.	1918
Kneebone, Christopher S., Woodville-road, Woodville, S.A.	1914
Meikle, R. A. Redvers, Dee-street, Mount Morgan, Q. ..	1920
Paull, N. C., Hampton-Cloncurry Copper Mines Ltd., Cloncurry, North Q.	1910
Plant, G. H. D., "Thornburgh," Charters Towers, Q. ..	1910
Roberts, Reginald A. J., "Clydeville," Beryl-street, Broken Hill, N.S.W.	1912
Russell, James L., c/o P. O'C. Russell, Elizabeth-street, Brisbane, Q.	1913
Smith, Eugene, 82 Victoria road, Auburn, Vic.	1913
Southon, Ronald D., Broken Hill South Mine, Broken Hill, N.S.W.	1912
Symonds, G. B. L., 174 Wolfram-street, Broken Hill, N.S.W.	1916
Taylor, Augustus, "Bernefay," Margate-street, Kogarah, N.S.W.	1908
Taylor, E. Foulkes, Cobham, Woodside, G.S. Railway, W.A.	1913
Thompson, David, Cardross, Q.	1910
Turner, William A., 17 Station-street, Camberwell, Vic. ..	1914
Uren, Wm. T., Salmon Mine, Dolomite, Q.	1909

Names and Addresses.	Date of Election.
Veitch, Neil A., Hampden-Cloncurry Copper Mines Ltd., Kuridala, North Q.	1911
White, James Murdock, c/o Malaya Tin Corporation Ltd., Puket, West Siam	1919
Williams, W. H. (jun.), Assistant Inspector of Mines, Rockhampton, Q.	1914
Wishart, J. W., H.M.A.S. *Torrens*, G.P.O., Sydney, N.S.W.	1910
Yates, Donald, Mayfield, Newcastle, N.S.W.	1914

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(INCORPORATED).

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LOCAL CORRESPONDENTS:

South Australia	H. W. Gartrell, The University, Adelaide.
New South Wales	F. Danvers Power, Sydney.
Western Australia	F. W. R. Godden, Hampton Plains.
New Zealand	D. B. Waters, Dunedin.
Tasmania	Russell M. Murray, Mount Lyell.
North Queensland	Murray Russell, Brisbane.

BRANCH SECRETARIES:

Sydney	F. Danvers Power, 33-39 Hunter Street, Sydney, N.S.W.
Kalgoorlie	F. W. R. Godden, Hampton Plains.
Broken Hill	C. H. J. Clayton, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. Patterson, Mount Morgan, Q.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 Queen Street, Melbourne, Victoria.

Institute Matters.

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MINUTES OF MEETINGS.

OF THE EXECUTIVE COMMITTEE.

(Summary).

MAY 3RD, 1921—1 P.M.

The Treasurer's report showed that receipts since last meeting were—Subscriptions, £177 6s. 3d.; Interest, £6 5s.

Accounts to the amount of £156 were passed for payment, and included—printing Proceedings No. 39, £124; Postage, £17.

Certificate of Incorporation was presented and showed that registration was effected on 7th April.

The Chairman declared Dr. F. L. Stillwell elected as a member of the Institute by ballot of members of Council.

Nominations as follow were approved for ballot:—As Member—Mr. Hector John Harrison; as Associate Members—Messrs. John Lemon Sampson and Revel Tinworth.

The resignation of Mr. W. B. Blyth (Associate Member) was accepted.

A letter was submitted from Mr. G. H. Knibbs, Director of the Institute of Science and Industry, requesting the views of the Institute on the proposals made to the Institute of Science and Industry for the publication of a book on "The Mineral Resources of Australia." After discussion it was resolved that the Aus. I.M.M. is of opinion that such a publication is desirable and necessary, but considers that the work should be undertaken under the control of the Institute of Science and Industry, assisted by a committee representing the various State Mining Departments, the Aus. Inst. Mining and Metallurgy (Incorporated) and similar bodies.

Papers as follow were submitted and referred to the Publication Committee :—

(1). "Ventilation : Metalliferous Mines," by T. G. Hanton.
(2). "The Artificial Ventilation of the Broken Hill Proprietary Mine," by R. T. Slee.
(3). "The Use of Explosives in Steel Works," by R. T. Slee.

The question of the locality of the First Ordinary Meeting, 1921, was discussed but no decision arrived at.

MAY 30TH, 1921—7 p.m.

The Treasurer's report showed that receipts since last meeting were—Subscriptions, £73 ; Advertisements, £5 ; and Sales, 2s. 6d.

Accounts to the amount of £62 were passed for payment.

A letter from the Institute of Science and Industry showed that the Director concurred in the general principal of control suggested by the Aus. I.M.M. in the proposal to publish a book on the Mineral Industry of Australia.

It was resolved that the First Ordinary Meeting, 1921, be held in Sydney at a date to be arranged later.

Nominations as follow were approved for ballot :—As Associate Members—Messrs. Eric W. Hughes, Christopher Stephen Kneebone, and Eric Hunter Disney White.

As a result of ballot, the chairman declared the following elected to the Institute:—As Member—Mr. Hector John Harrison; as Associate Members—Messrs. John Lemon Sampson and Revel Tinworth.

The following were admitted as Students:—Messrs. Hugh Bert Howlett and Alexander Ashton McLeod.

Representatives of the Institute were appointed to interview the Hon. the Minister of Mines, N.S.W., and urge an amendment of the Mines Regulations Act, 1901, in the direction of modifying the provisions for employment of certificated engine-drivers for such work as starting and stopping pumps and machinery underground other than rock drills and sinking pumps.

The Report of the Annual Meeting of the Broken Hill Branch was submitted and received, and the election of officers for the year 1921-22 was approved.

Resolved that the Donation Trust Account (£152 10s.) form the nucleus of a larger fund (£1000 if possible); that the interest thereon be used to provide one or more annual prizes for papers contributed by Associate Members, Juniors and Students, and that members be invited to contribute to the fund.

Representatives were appointed to confer with representatives of the Institution of Engineers of Australia in regard to the proposal to form an Engineering Council.

JUNE 27TH, 1921—8 P.M.

The Treasurer's Report was presented and accounts to the amount of £95 (including printing £77) were passed for payment.

As a result of the ballot, the chairman declared the following elected as Associate Members of the Institute:—Messrs. Eric William Hughes, Christopher S. Kneebone and Eric H. D. White.

A report of the deputation from the Institute which waited upon the Hon. the Minister for Mines, N.S.W., in the matter of the certification of engine-drivers was received. The report showed that the deputation had a sympathetic hearing; that draft regulations were framed for the removal of the anomalies which at present obtain; that the system adopted in W.A. for granting certificates to miners to operate Holman hoists would be favorably considered.

A report was submitted in regard to the proposal to form an Engineering Council representing the various Australian Institutes, and the suggestion that a conference be convened in Sydney at the time of the First Ordinary Meeting, 1921, to discuss the matter, was adopted.

Resolved that arrangements be made, if possible, to hold the First Ordinary Meeting in Sydney in August instead of September.

The action taken in requesting the Institution of Mining and Metallurgy, London, to forward I.M.M. screens true to standard was approved.

In regard to the Donation Fund Account it was resolved (1) that prizes of £10 each be open for competition in each State and New Zealand; (2) that the question of payment from interest or from capital be deferred until after the Sydney meeting; (3) that details be arranged by the Publication Committee; (4) that the competition be restricted to Student members of the Institute.

The publication of advance copies of a paper by Mr. P. Hampton Warren on "Mechanical Methods of Allying Dust" was approved.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holiays.

MEMBERSHIP.

Since the issue of Proceedings No. 41, the following have been admitted to the Institute :—

Member.

Names and Addresses.

HARRISON, HECTOR JOHN, 656 Chapple Street, Broken Hill, N.S.W.

Associate Members.

HUGHES, ERIC WILLIAM, School of Mines, Adelaide, S.A.
KNEEBONE, CHRISTOPHER STEPHEN, Woodville Road, Woodville, S.A.
SAMPSON, JOHN LEMON, Broken Hill Associated Smelters Ltd., Port Pirie, S.A.
TINWORTH, REVEL, Ballarat East, Vic.
WHITE, ERIC HUNTER DISNEY, School of Mines, Bairnsdale, Vic.

Students.

HOWLETT, HUGH BERT, School of Mines, Bairnsdale, Vic.
MCLEOD, ALEXANDER ASHTON, Maffra, Vic.

FIRST ORDINARY MEETING, 1921.

The Council has decided that the First Ordinary Meeting, 1921, be held in Sydney during the week 22nd to 27th August. A programme is being arranged by the Sydney Committee and will shortly be circulated. Members intending to be present should notify the Secretary as soon as possible, in order that arrangements may be made for travelling concessions and accommodation.

STUDENTS' PRIZE FUND.

This fund was inaugurated by Mr. J. W. Sutherland (Past President) donating £52 10s. for the purpose of encouraging students in mining and metallurgy by means of prizes for papers contributed. During last year the fund was increased to £152 10s. by donations of £50 each from Messrs. G. H. Blakemore (member of Council), and W. E. Wainwright (Past President). The Council has decided to invite members to contribute to the fund in order that a sufficient amount may be thus raised to enable the interest to provide prizes of £10 each yearly for the best papers contributed by students in each of the Australian States and New Zealand; that, pending the receipt of a sufficient amount by donation, the balance of the interest required be paid from the Institute funds.

PUBLICATIONS.

Papers appearing in this issue are :—

- "A Proposed Copper Metallurgical Process." By Percy Burbidge.
- "The Artificial Ventilation of the Broken Hill Proprietary Mine, N.S.W." By R. T. Slee.
- "The Use of Explosives in Steel Works." By R. T. Slee.
- "Mechanical Methods of Allaying Dust" (with discussion). By P. H. Warren.

Written contributions to the discussion on these papers is invited by the publication committee.

ENGINEERING COUNCIL.

Some progress has been made in regard to the proposal to inaugurate some scheme of federation of kindred associations. It is probable that this matter will receive consideration at the forthcoming First Ordinary Meeting in Sydney in August.

PRIZE PAPER.

A prize of £25, contributed by the Mining Managers' Association, Broken Hill, for the best paper contributed by a member of the Broken Hill Branch of the Institute, has been awarded to Mr. Herbert Lavers for his paper entitled "Notes on Tungsten."

This paper will be published in a later number of the proceedings.

ELECTION OF OFFICE-BEARERS.

Members are reminded that according to Clauses 37 to 53 of the Articles of Association (see Proceedings No. 41) nominations of President and Members of Council should reach the Secretary not later than 1st September, 1921. Nominations are invited in accordance with the Clauses above referred to. The President and Councillors so elected will not take office until the 1st of January, 1922.

BRANCH NOTICES.

BROKEN HILL BRANCH.

WEDNESDAY, 11TH MAY, 1921, at 8 p.m.

Mr. Andrew Fairweather occupied the chair.

The following were elected office-bearers for the ensuing year :—

Chairman—C. C. FREEMAN.
Vice-Chairmen—R. T. SLEE AND W. D. WHITEMAN.
Hon. Secretary—C. H. J. CLAYTON.
Hon. Treasurer—P. H. WARREN.
Hon. Auditor—C. D. CHERRY.
Committee—A. S. CLARK (Amalgamated Zinc De Bavey's Ltd.), H. J. HARRISON (Broken Hill North Ltd.), R. D. NEVETT (Junction North Co.), W. D. WHITEMAN British Broken Hill), H. LAVERS (Block 14 Co.), N. ROBERTS, E. HOLDER (Central Mine), V. A. HAIGH (Block 10), E. HENDERSON (Broken Hill Pty.), and W. CHOMLEY (Zinc Corporation Ltd.)

The balance-sheet, showing a credit balance of £7 12s., was submitted and adopted.

Mr. Fairweather then presented the prize of £25 donated by the Mining Managers' Association to Mr. Herbert Lavers for his paper "Notes on Tungsten," and in his remarks deplored the apathy of younger writers who were missing an opportunity for self-education by neglecting to write up subjects for discussion.

Mr. Lavers, in thanking the Mining Managers' Association through the chairman, said he considered that the poor response to the invitation to write papers was due to lack of facilities provided. He considered that the development of flotation had been retarded by the secrecy observed.

The question of amending the Mines Regulation Act, 1901, dealing with the necessity of employing only certificated drivers to start and stop pumps and all machinery underground other than rock drills and sinking pumps, was referred to the Council.

Discussion of the advisability of introducing a Mine Foreman's Certificate of Competency was adjourned *sine die.*

MOVEMENTS OF MEMBERS.

James Barr is now with J. A. Russell & Co. (Malayan Colleries Ltd.), Kuala Lumpur, Federated Malay States.

B. V. Barton, recently Mine Superintendent of the Bendigo Amalgamated Goldfields Ltd., Vic., sailed for South Africa at the end of June to fill a position on the staff of the Rhodesia Broken Hill Development Corporation, Broken Hill, Rhodesia.

Joseph Grigg has returned from the Federated Malay States, and is at present at Fremantle, W.A.

Ralph V. Berriman has been appointed Principal of the Technical School, Port Pirie, W.A.

G. J. Gray, late of Cobar, N.S.W., is now at the Laloki Mine. Port Moresby, Papua.

John McGeachie, late Manager of the Aberdare Colleries, Cessnock, N.S.W., has commenced private practice as a Consulting Mining Engineer, Coal Expert and Colliery Viewer at 28 O'Connell Street, Sydney, N.S.W.

F. M. Murdoch has been appointed Chief Chemist to the Technical Commission of Enquiry, Protestant Hall, Broken Hill N.S.W.

John W. Moule (member of Council) has resigned from the Burma Mines Ltd., and is visiting London. His address now is—Herberton, Nth. Queensland.

Richard A. Rusha, Abu Tin Co. Ltd., Northern Nigeria, reports that he is leaving Nigeria very shortly for London.

Malcolm B. Scott has left Hobart, where he was engaged by the Electrolytic Zinc Co. of Australasia, and is at present in Melbourne.

J. B. Shaw has been appointed Superintendent of the Tube Factory in connection with Metal Manufacturers Ltd., at Port Kembla, N.S.W.

C. H. Stokes is now engaged by the Commonwealth Steel Products Co. Ltd., at Waratah, Newcastle, N.S.W.

Charles G. L. Thompson, recently with the New Guinea Copper Mines Ltd., Port Moresby, Papua, is at present in Melbourne.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY

From 31st March, 1921 to 30th June, 1921.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
Royal Society of Victoria : Proceedings, Vol. XXXIII.		Melbourne
Department of Mines, Queensland : Geological Survey, Publication, No. 266		Brisbane
Royal Society of Queensland : Proceedings, Vol. XXXII.		Brisbane
Department of Mines, South Australia : Review of Mining Operations, No. 33		Adelaide

The University of Adelaide :
Calendar, 1921 - - - - Adelaide
Department of Mines, Western Australia :
Bulletin, Geological Survey, No. 78 - - Perth
Department of Mines, Tasmania :
Bulletin, Geological Survey, No. 32 - - Hobart
Institution of Mining Engineers :
Transactions, Vol. LX., Part 2, Vol. LXI., Part 1 London
Institution of Mining and Metallurgy :
Bulletins, Nos. 198, 199 - - London
North of England Institute of Mining and Mechanical Engineers :
Annual Report of Council and List of Members, December, 1920 - - - Newcastle
Imperial Mineral Resources Bureau :
Reports—Aluminium and Bauxite, Antimony, Arsenic, Bismuth, Asbestos, Borates, Chrome Ore and Chromium, Zinc, Nitrates, Monazite, Magnesite, Fuller's Earth, Felspar, Cobalt
Mining Law—Vol. I.—Algeria
,, ,, Vol. II.—West Africa - London
Annales des Mines :
Vol. XI., Parts 1-3 - - - - Paris
Geological Survey of India :
Records, Vol. LI., Part 3 - - - Calcutta
Department of Mines, Canada :
Memoirs, Nos. 118-123
Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and other Metals in Canada during 1919
Museum Bulletin, Geological Survey, No. 31 - Toronto
American Institute of Mining and Metallurgical Engineers :
Mining and Metallurgy, Nos. 171-173 - New York
American Society of Civil Engineers :
Transactions, Vol. LXXXIII. - - New York

RECENT ARTICLES ON MINING MATTERS.

(31st March, 1921 to 30th June, 1921.)

NOTE.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c.. due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queens'and Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Transactions*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng. New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London.

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

GEOLOGICAL.

The Need of Quantitative Methods in Applied Geology. C. H. White. (8) April 30, 1921.
Mine Geological Surveying. G. J. Mitchell. (6) March 5, 1921.
Estimation of Mineral Reserves. J. D. Kendall. (35) Feb., 1921.

MECHANICAL.

The Application of Cement Mixtures by Machinery. G. J. Young. (6) March 26, 1921.
Fan Equipment for Metal Mines. T. H. Arnold. (6) April 2, 1921.
Shop Hammers. (6) May 14, 1921.
Internal-Combustion Engine Development. W. J. Walker. (37) Journal, Feb., 1921.
Mechanical Loading of Ships. F. T. Parker. (37) Journal, March, 1921.
The Generation of Steam. Sir J. Dewrance. (37) Journal, April, 1921.
The Desirability of Standardization in the Testing of Welds. F. M. Farmer. (37) Journal, April, 1921.
Breakage and Heat Treatment of Rock-Drill Steel. B. F. Tillson and E. M. Franklin. (29) May, 1921.
Steel Chimneys and Linings in Copper-Smelting Plants: Discussion. A. G. M'Gregor. (29) Nov., 1920.
Calculations of Waste-Heat Boilers for Open-Hearth Furnaces. T. R. Tate. (29) Jan., 1921.
The Transmission of Power by Waves. P. J. Risdon. (35) March, 1921.

METALLURGICAL.

Amalgamation in Stamp Mills. W. Motherwell. (8) March 19, 1921.
The Development of a Vibrating Machine. B. A. Mitchell and G. B. Rosenblatt. (8) March 26, 1921.
Steel Rails as Ball-Mill Lining. E. B. Morse. (8) April 2, 1921.
Cottrell Process of Electrical Precipitation. (8) April 9, 1921.
Recovery of Gold from Black Sand. J. A. Davis and J. Gross. (8) April 9, 1921.
Electric Furnace Practice at Treadwell. W. E. Cahill. (8) April 16, 1921.
The Alaska Juneau Mill. V. C. Clausen. (8) May 7, 1921.
Chloridizing and Leaching as Practised in Sweden. N. Ostman. (6) March 5, 1921.
Chloridizing Roasting of Copper Ore. V. Carlsen. (6) March 12, 1921.
A New Method for Copper Assaying. G. J. Hough. (6) March 19, 1921.
The Construction and Operation of a Cyanide Plant in Ecuador. P. C. Schraps. (6) April 2, 1921.
Recent Metallurgical Practice on the Rand. (6) April 9, 1921.
Converting Mixed High-Grade Matte and Copper. C. A. Grabill. (6) April 30, 1921.
Copper-Leaching Practice. F. E. Lathe. (6) May 14, 1921.
Cooling and Humidifying Roaster Gases for Cottrell Process. (6) May 14, 1921.
The Development of the Rod Mill. E. H. Robie. (6) May 28, 1921.
The Engels Copper Mine and Mill, California. G. J. Young. (6) May 28, 1921.
Drying Fine Concentrates. (6) May 28, 1921.
Important Factors in Talc Milling Efficiency: Discussion. R. B. Ladoo. (29) Jan., 1921.
Electrolytic Zinc Plant of Anaconda Copper Mining Co., at Great Falls, Mont.: Discussion. (29) Dec., 1920.
Roasting and Chloridizing of Bolivian Silver-Tin Ores: Discussion. M. G. F. Sohnlein. (29) Aug., 1920.
Converting High-Grade Matte into Magnesite-Lined Converters. H. C. Robson. (29) Jan., 1921.
Milling Process in South-West Wisconsin Zinc District. D. J. Hayes. (29) April, 1921.
Crushing, Grinding, and Agitation of Tonopah Ores. H. A. Burk. (29) April, 1921.
Refining and Precipitation in the Tonopah District of Nevada. F. C. Ninnis and W. W. Anderson. (29) April, 1921.
The Physical Basis of Tin Dressing. R. T. Hancock. (35) Feb., 1921.
The Estimation of Phosphoric Acid by the Molybdate Method. J. E. Clennell. (35) March, 1921

MINING.

Steam Shovel Operations at the United Verde Mine. L. A. Parsons. (8) Serial commenced April 2, 1921.

The New Concrete Shaft of the Chief Consolidated Mining Company. A. B. Parsons. (8) April 30, 1921.

Tunnelling Through Soft Ground. R. W. Jones.

Sinking and Concreting Pyne and Songo Shafts. J. H. Stovel. (6) April 23, 1921.

Study of Underground Electrical Prospecting. C. Schlumberger. (6) Serial commenced May 7, 1921.

Sinking Van Dyke No. 1 Shaft. E. R. Rice. (6) May 21, 1921.

Scheme for Working the City Deep Mine at a Depth of 7,000 Feet. E. H. Clifford. (25) Bull. No. 197.

Run-off and Mine Drainage. H. N. Eavenson. (29) Jan., 1921.

Skip Hoisting for Coal Mines. A. Allen and J. A. Garcia. (29) Feb., 1921.

Coal Pillar Drawing Methods in Europe. G. S. Rice. (29) Feb., 1921.

Factors to be Considered in Interpretation of Prospect Drilling Results. H. C. George. (29) Feb., 1921.

MISCELLANEOUS.

Valuing Partly-Exhausted Mines. M. Webber. (8) Serial commenced March 19, 1921.

The Cause and Control of Lead Poisoning. W. S. Slemmons. (8) March 26, 1921.

Prospecting, Past and Future. T. A. Rickard. (8) April 23, 1921.

The Value of Research in Mining and Metallurgy. S. H. Dolbear. (6) Feb. 26, 1921.

Industrial Development of Zinc. S. S. Tuthill. (6) March 5, 1921.

The Uses of Graphite. (6) March 5, 1921.

The Problem of Domestic Copper Consumption. H. A. C. Jenison. (6) March 19, 1921.

Dust Control and Ventilation in Metal Mines. D. Harrington. (6) April 30, 1921.

Notes and Records of Mining Costs. A. E. Pettit. (25) Bull. No. 198.

Judging the Quality of Portland Cement: Discussion. R. J. Colony. (29) Jan., 1921.

Calculation of Ore Tonnage and Grade from Drill-Hole Samples: Discussion. J. E. Harding. (29) Jan., 1921.

Dust Ventilation in Metal Mines. D. Harrington. (29) Feb., 1921.

The Health of the Underground Worker: Discussion. A. J. Lanza. (29) Feb., 1921.

Why the Metric System Should Not Be Adopted. W. R. Ingalls. (29) May, 1921.

Iron Ore Deposits of Queensland. (35) April, 1921.

Manganese: Uses, Preparation, Mining Costs, &c. C. M. Weld. (35) April, 1921.

Jan

PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy

(INCORPORATED).

NEW SERIES.

No. 43.

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

30th SEPTEMBER, 1921.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY (INCORPORATED), MELBOURNE.

Australasian Institute of Mining and Metallurgy

(INCORPORATED).

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Vice-Presidents:

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COLIN FRASER, S.A.

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G. D. DELPRAT	New South Wales
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GEO. H. BROOME	Victoria
GEORGE WEIR	New South Wales
J. W. SUTHERLAND	Western Australia

Secretary:

D. L. STIRLING, Melbourne, Vic.

LOCAL CORRESPONDENTS:

South Australia	H. W. GARTRELL, The University, Adelaide.
New South Wales	F. DANVERS POWER, Sydney.
Western Australia	F. W. R. GODDEN, Hampton Plains.
New Zealand	D. B. WATERS, Dunedin.
Tasmania	RUSSELL M. MURRAY, Mount Lyell.
North Queensland	MURRAY RUSSELL, Brisbane.
Papua	W. G. LANGFORD, Oilfields, Papua.

BRANCH SECRETARIES:

Sydney	F. DANVERS POWER, 33-39 Hunter Street, Sydney, N.S.W.
Kalgoorlie	F. W. R. GODDEN, Hampton Plains.
Broken Hill	C. H. J. CLAYTON, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. PATTERSON, Mount Morgan, Q.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 QUEEN STREET, MELBOURNE, VICTORIA.

Institute Matters.

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MINUTES OF MEETINGS.

OF THE INSTITUTE.

First Ordinary Meeting, 1921, Sydney, 22nd to 27th August.

Monday, 22nd August.

The First Ordinary Meeting, 1921, opened at 9.30 a.m. on Monday, 22nd August, at No. 3 Class-room, University Chambers, Phillip-street, Sydney, kindly placed at the disposal of members by Professor Peden. Mr. G. C. Klug (vice-president) occupied the chair, and in doing so apologized for the unavoidable absence of the president (Professor Chapman).

The secretary read the notice convening the meeting.

Minutes of the Annual Meeting, 1921, were confirmed.

The Chairman reported that a meeting of the full Council had been convened to take place that morning; but, as there were not sufficient members of Council present to form a quorum, it was decided that members of the Institute present be given an opportunity to discuss Institute matters and make recommendations.

Announcements were made in respect to arrangements for the remainder of the meeting.

The business meeting then adjourned until 2 p.m., and members proceeded to the Mining Museum in George-street, where an inspection was made of the magnificent collection of rocks and minerals.

Messrs. G. C. Klug and A. S. Kenyon attended (as the Institute's delegates) a conference convened by the Institution of Engineers, Australia. The conference was held at the Royal Society House, Elizabeth-street, where the proposal to form an Engineering Council was discussed by delegates representing the three Federal Institutes—viz., Institution of Engineers, Australia, the Australian Chemical Institute, and the Australasian Institute of Mining and Metallurgy.

The business meeting was continued at the University Chambers at 2 p.m. At this and subsequent meetings and at all functions during the convention Mr. G. C. Klug presided.

The Chairman proposed a vote of thanks to Messrs. F. Danvers Power and Wm. Poole and other members of the Sydney Committee for the admirable arrangements made in connection with the meeting. The vote was carried by acclamation.

The following resolutions were unanimously carried :—

(1) "That this meeting of members of the Australasian Institute of Mining and Metallurgy places on record its appreciation of the good work carried out by the Mining Museum, and trusts that the magnificent collection of rocks and minerals will be kept intact and available to the public as a permanent exhibit showing the value of the mining industry of New South Wales, in order that it may continue to assist those who desire to exploit the mineral wealth of the country ; and that a copy of this resolution be forwarded to the Honourable the Minister for Mines."

(2) "That a letter of thanks be sent to Professor Peden for granting the Institute the use of a room in which to hold its meetings."

The Chairman announced that the conference *re* proposed Engineering Council, held that morning, was very successful, and it was almost certain that as a result a Federal Engineering Council would be constituted. A further sitting would take place on Thursday next.

Suggestions were then invited regarding the locality of the First Ordinary Meeting, 1922, and it was resolved that it be a recommendation to the Council that the meeting be held at Port Pirie, S.A. It was also mentioned that the Council was considering the practicability of holding the First Ordinary Meeting, 1923, in New Zealand, so as to dovetail with the meeting of the Australasian Association for the Advancement of Science.

Reference was made by the Chairman to the fund established by the leading base metal companies and a large coal-mining interest for providing bursaries to students in mining and metallurgy. The Institute was represented on the Bursaries Selection Committees.

An announcement was also made that the Imperial College of Science and Technology, London, with which the Royal School of Mines is incorporated, was offering two Research Fellowships of £300 a year each, tenable for one year and possibly renewable for a second year, to aid in carrying out investigations or research connected with mining, mining geology, metallurgy, or the technology of oil. The Australasian Institute of Mining and Metallurgy represented the Royal College of Science and Technology in Australia in the matter, and all applications should be made to the secretary of the Institute.

It was urged that the Institute should secure greater recognition by the Federal and State Governments. One of the principal reasons for obtaining this recognition was, it was urged, to prevent reports by incompetent persons being used for the flotation of mining and industrial companies. The Chairman explained that the proposed Federal Council would, when constituted, be a power for good in this matter.

Members were reminded that a Donation Trust Fund had been inaugurated by a past-president of the Institute (Mr. J. W. Sutherland), who had contributed fifty guineas for prizes to mining and metallurgical students for the purpose of encouraging them in their studies. This fund has been supplemented by similar amounts from Mr. W. E. Wainwright (past-president) and Mr. G. H. Blakemore (member of Council). Further contributions from members were invited in order that a sufficient sum might be raised, the interest on which would provide for prizes for essays by mining students in the Australian States and New Zealand.

The Chairman announced that Mr. A. T. Danks, of Melbourne and Sydney, had again offered a prize of £10 for the best paper, contributed by students taking part in the present meeting, descriptive of the plants and works visited during the excursions.

Mr. Wm. Poole urged that examination conditions for mining managers' certificates should be uniform throughout the States and New Zealand, and that certificates issued by one State should then be accepted by the other States. It was resolved that the Council be requested to take the necessary steps to carry this proposal into effect. (It was subsequently explained that the Council already had this matter in hand.)

Mr. Poole suggested that the matter of uniform conditions of employment of underground engine-drivers and motor attendants in New South Wales should receive the attention of the Council.

Mr. C. H. J. Clayton stated that most of the States had re-modelled Acts dealing with that matter. New South Wales had, however, not done so.

Mr. Poole contended that it was highly desirable that the whole of the Commonwealth and New Zealand be organized into Branches, with definite areas, under the supervision of Branch Committees. After considerable discussion it was decided that an opportunity be given later on during the meeting for discussing the subject.

Discussion of papers was then proceeded with in the following order :—

(1) "Mechanical Methods of Allaying Dust," by P. Hampton Warren. Discussion on this paper was preceded by a summary by Mr. C. H. J. Clayton of the main points of the paper and discussion to date by the Broken Hill Branch.

(2) "Determination of Minute Amounts of Lead in Water, etc.," by D. Avery, A. J. Hemingway, V. G. Anderson and T. A. Read. A *resume* of the paper was given by Mr. D. Avery.

The meeting then adjourned until 8 o'clock on Tuesday evening next.

Members left Sydney by the 6.35 p.m. train for Lithgow, arriving there at 11 p.m.

TUESDAY, 23RD AUGUST, 1921.

At 9.30 a.m. the party proceeded to inspect Messrs. Hoskins' iron and steel works. They were driven to the works in cars provided by the company. Upon arrival at the works the party was met by Messrs. Cecil Hoskins and A. Sidney Hoskins (directors) and John Evans, mine manager. Here the party divided into small sections. Each section, under the guidance of a member of the staff, was shown the whole process of manufacture of iron and steel. The following summary of the main points of interest concerning the company and its operations was supplied to each member of the party :—

"The company is owned and operated by Mr. C. H. Hoskins and members of his family. The capital of the company is 2½ million pounds (£2,500,000), and the number of men employed at present approximately 2500 ; but with the extensions that are contemplated in the near future this number will be considerably increased.

"The various plants operated by the company are as follows :—

"The main iron and steel works are situated at Lithgow, on the Blue Mountains, at an elevation of 3000 ft. above sea level, and 96 miles west of Sydney.

"An engineering and cast-iron pipe works are situated at Sydney and Rhodes (a suburb of Sydney).

"A colliery, comprising 5000 acres of coal land, together with coking plant, is situated at Dapto, on the coast, 56 miles south of Sydney, in the southern coalfield.

"The company has recently purchased 400 acres of land on the coast at Port Kembla, 8 miles distant from the above colliery and coking plant, with a view to establishing a modern steel works, to allow for future extensions whenever required. One of the directors has just returned from an extensive tour of England, U.S.A., and Canada, where he gathered information regarding the most modern iron and steel plants, in order that the new plant on the coast, together with numerous alterations and extensions to the existing plant at Lithgow, should be along the most modern lines.

"The company is practically self-supporting for all its raw materials, as it owns numerous iron-ore properties in New South Wales and Tasmania, together with extensive coal properties and limestone deposits.

"In addition to the above, it also owns several manganese ore properties, the ore being of very high quality, from which many thousands of tons of high-grade ferro-manganese have been produced during the past five years.

"The works at Lithgow are situated in the heart of the western coalfield, the coal for use in the steel works going straight into the works from the mine, which is less than a quarter of a mile distant from the mills. The company is also opening up an additional coal mine at Lithgow, 2 miles from the works, consisting of about 3500 acres of good coking coal. This coal seam is 10 ft. thick at a depth of 300 ft., 6 ft. of which is good coal, containing about 32 % volatile matter and 8 % of ash. The remaining 4 ft. is inferior coal containing about 12 % of ash, which is used mainly for firing boilers. The company's coal property at Dapto consists of 5000 acres of coal land containing four seams of coal, three of which contain good coal, the top seam containing 8 % ash, 27 % volatile matter, and makes a very strong coke for blast-furnace work.

"The company holds numerous iron-ore properties, which together are estimated to contain between 80,000,000 and 100,000,000 tons of good ore. The ore for the present steel works at Lithgow is drawn from Tallawang (100 miles north-west), Carcoar (80 miles south-west), and Cadia (100 miles south-west of Lithgow). The first-mentioned ore is a magnetite containing 60 % of iron ;

the latter two deposits are red hematite, containing 57–58 % of iron. Numerous other deposits are also held about 100 miles south-west and south of Lithgow.

"The limestone for the Lithgow works is obtained from the company's own quarries, 25 miles west of the steel works. The manganese ore is obtained at Grenfell, 156 miles west of Lithgow.

"The whole of these supplies are brought by rail to Lithgow on the State railways. Numerous other ore deposits, containing red hematite, with about 58 % of iron, are held in New South Wales, to be used at the proposed steel works on the coast at Port Kembla. There are also very extensive magnetite deposits in Tasmania, which will be shipped to the steel works at Port Kembla.

"The Lithgow steel works consist of a coke oven plant of 95 Belgian-type non-recovery ovens, with a capacity of 1500 tons of coke per week. This supply of coke is augmented from a similar plant at Dapto. There are two blast-furnaces, which have a combined capacity of 150,000 tons per annum. These are at present hand-filled, but it is expected will be enlarged and mechanically charged in the near future. Of the iron produced, approximately half is of foundry quality, the other half being sent direct in 30-ton ladles to the steel plant. The blast furnaces are blown with three Parsons turbine blowers, the largest of which has a capacity of 40,000 cub. ft. per minute at 18 lb. pressure per square in. The usual working pressure is about 10 lb. per sq. in., and the blast temperature 1100° Fahr. Owing to all the materials being low in sulphur, no difficulty is experienced in making first-class iron, both for foundry and steel-making purposes, the coke containing .65 % sulphur.

"The open-hearth shop consists of three modern basic open-hearth furnaces of 50 tons, 70 tons, and 100 tons capacity respectively. A fourth furnace is now being added, which also will have a capacity of 100 tons. The furnaces are charged by an overhead slewing type charger, and the steel ladles are handled by a 100-ton electric crane, which also handles the hot metal from the blast furnaces. This crane is to be transferred at once to the charge side, and a crane of 150 tons capacity will take its place for handling the steel ladles. The ingots at present are taken hot to the 28-in. blooming and finishing mill, which rolls blooms and billets of standard sizes below 8-in. square. The blooming rolls are driven by a two-cylinder engine, 42 x 60, developing approximately 5000 h.p., the finishing mill being driven by a three-cylinder Davey engine, 32 x 42. The capacity of this mill is 4000 tons of billets per week, or a slightly lessser tonnage on finished sections; but owing to lack of steel this mill is at present only operating one shift.

"Two 10-in. bar mills are being erected, the first of which has just commenced operations. These mills will have a capacity of 1200 tons of small bars per week, and arrangements are provided for adding continuous stands of roughing rolls at a later date when required. The 18-in. two-high mill handles intermediate sizes.

"The works have their own engineering shops and foundries, and most of the alterations and extensions to the plant are carried out in these departments. All classes of carbon steels are manufactured, including a large variety of spring steels, together with numerous special qualities for the manufacture of small arms, as well as other specifications.

"The cast-iron pipe and general engineering works are situated in Sydney and Rhodes, a suburb of Sydney, on the Parramatta River. These pipe plants are easily the largest in Australia, and the plant at Rhodes is along the most modern lines, and is claimed to be the finest plant for this class of work in the world. The capacity of the cast-iron pipe works is 1500 tons per week, working one shift of 8¾ hours.

"The engineering shops have carried out many large enterprises, chief among which is the pipe-line for the supply of water to Coolgardie, which consists of 360 miles of locking-bar pipes, 28 in. in diameter and 28 ft. long, this being one of the largest engineering works carried out in the southern hemisphere. The large 6-ft. water mains supplying Sydney from the reservoirs, situated 35 miles distant, were manufactured by this company, together with many other large undertakings."

Upon completion of the inspection the party motored to the town hall, and was there entertained at lunch by Messrs. Cecil and A. Sidney Hoskins. After full justice had been done to the excellent repast, Mr. Cecil Hoskins, in a short speech, welcomed members to Lithgow. Mr. G. C. Klug responded on behalf of the Institute. Mr. J. Ryan, M.L.C., gave the toast of "Local Industries." Members enthusiastically joined in the toast with musical honours. Mr. A. Sidney Hoskins responded on behalf of the Hoskins Iron and Steel Co. Ltd., and Mr. S. R. Radcliffe for the Commonwealth Small Arms Factory. The toast of "The Mayor" was proposed by Mr. Klug and acknowledged by Alderman Evans.

A visit of inspection was then paid to the Commonwealth Small Arms Factory, under the guidance of the manager (Mr. S. R. Radcliffe), assistant manager (Mr. James D. Statton), and other members of the staff. There members made the most of the limited time at their disposal, and came away deeply impressed with the wonderful mechanism employed in fashioning weapons of war.

The business meeting, adjourned from Monday, 22nd inst., was continued at Tattersall's Hotel, Lithgow, at 8 p.m. Discussion was commenced by Mr. J. M. Bridge on Mr. P. H. Warren's paper, "Mechanical Methods of Allaying Dust."

Mr. Clayton advocated investigation into improvements in rock-drill steel in order to keep pace with the improvements in rock-drills.

The Chairman invited discussion on the following papers, already in the hands of members:—

"A Proposed Copper Metallurgical Process," by P. Burbidge.

"The Artificial Ventilation of the Broken Hill Proprietary Mine, N.S.W.," by R. T. Slee.

"The Use of Explosives in Steel Works," by R. T. Slee.

"Determination of Minute Amounts of Lead in Water," by D. Avery, A. J. Hemingway, V. G. Anderson, and T. A. Read.

"Ventilating Metalliferous Mines: a Method of Attack," by Thos. G. Hanton.

"Description of New Plant at South Mine, Broken Hill," by W. E. Wainwright and J. C. Cunningham.

He hoped that written contributions to the discussions on these papers would also be sent in.

Mr. Poole commenced a discussion on Mr. Thos. G. Hanton's paper, "Ventilating Metalliferous Mines."

The Chairman then suggested that they resume discussion on Institute matters. He had promised to give Mr. Poole an opportunity of bringing forward an important proposal in respect to the formation of the branches.

Mr. Poole then moved—"That (*a*) it is desirable that the whole of the Commonwealth and New Zealand be organized into branches; (*b*) that the committees of each branch actively watch the interests of the Institute within the territory of the branch, and to report to the Council such matters in which action seems desirable." He considered it was desirable that the whole of the Commonwealth and New Zealand be divided into branches. Taking New South Wales as an example, he said, there were only two branches—Broken Hill and Sydney. As soon as any area became sufficiently strong to run an active committee he favoured the formation of a branch there. He hoped that Newcastle would form a branch. He also expressed the hope that the Council would urge the branches into activity. They should look after the interests of the Institute and endeavour to secure papers for general discussion from men residing in those areas.

Mr. A. S. Kenyon seconded the motion. He said they had found, from the initial work of the Institute, that it was necessary to have representation in the various mining centres away from the head office. He believed that anything they could do to increase the number of branches would tend to increase the usefulness and effectiveness of the Institute. It would protect the professional men in the mining industry and improve mining operations generally.

Mr. Waterhouse said he would support the motion to a certain extent. He advocated that yearly meetings be held to give all members an opportunity of congregating together and discussing those topics which vitally interested them. He was in favour of holding meetings in Sydney, where they would be in touch with the technical authorities and the teaching profession generally. They would also be able to get the students from the University and the benefit of the University staff. They all realized that the curricula were not what they should be, and if meetings were held in Sydney he believed there would spring up a closer bond of sympathy between the members of the Institute and the teachers at the colleges and University.

Mr. J. M. Bridge said that wherever there was a band of enthusiasts he would say, Go ahead and form their branch. In connection with local correspondents he considered that every member should consider himself a local correspondent. Most members of the mining profession were busy men, but he thought that if they came across anything of importance in their particular State or district they should bring it under the notice of the Council. He did not favour the placing of any restrictions on the formation of branches.

Mr. Clayton supported the views expressed by Mr. Bridge.

Mr. Donaldson said that if they carried the resolution into effect he considered the branches should arrange gatherings in the form of annual meetings for the general benefit of the members. He favoured the holding of annual State meetings which would last, probably, only one or two days. A meeting of two days' duration held in Sydney, of New South Wales members, would, he thought, be conducive of much good.

Mr. Hartwell Conder spoke of the manner in which the mining men of Tasmania were scattered, and said it would be difficult for the men of the North-East Coast, for instance, to attend a congress held at Lyell.

Mr. Wm. E. Hitchcock advocated the formation of branches in Tasmania.

Dr. Murphy said if the Institute enlarged its activities along the lines suggested it would be doing the right service to the Commonwealth. He appealed for constructive criticism from all members of the Institute, and said that if such were offered it would be much appreciated. He mentioned the difficulty in keeping in touch with all the scientific journals which were being published.

Mr. D. Avery said the suggestion to hold joint meetings had already been carried out. In Melbourne the Chemical Institute had joint meetings with other societies whenever a paper of mutual interest was submitted. He did not see why the same sort of thing could not be introduced into their own branch. The speaker was not at all pessimistic about the establishment of real live branches in the various States.

The Chairman said he was a little diffident as to whether the present system would be improved by the resolution moved by Mr. Poole. He would like to see a co-ordination of interest between their own body and other Institutes, such as that of the Engineers and the Australian Institute of Chemists. At the present time a conference was being held, and they hoped to be able to get the respective bodies to agree to a resolution relative to the formation of a Federal Council which would look after the interests and the welfare of the professional men in the mining industry. The Melbourne University had recognized the value of the Institute, and had granted them representation on the engineering faculty. He thought it was up to the Sydney University to follow suit. They gave full credit to their members, such as those at Broken Hill, for coming forward with valuable contributions in the way of papers, and he was of opinion that others would follow the lead as soon as the industry improved. If it was the wish of the members, the speaker was sure the Council would welcome the proposal of Mr. Poole's and put it to the practical test. There was no great difficulty about having State branches, but he thought that annual meetings of members from the various States was better than having their own State meetings. They could have the former if it was desired, but his opinion was that better results would accrue by having visits from other State members, as it would give everyone an opportunity of discussing matters affecting their own particular State. The Chairman concluded by expressing the opinion that the present system would be hard to improve upon.

Mr. Donaldson submitted an amendment that the Council be asked to consider the possibility of holding annual meeting of members in the various States in addition to the annual meeting of the Institute.

The Chairman pointed out that the amendment was in reality a separate motion.

The motion was then put, and carried.

Mr. Clayton asked leave to bring several matters before the meeting. He wanted to know if they had any means of keeping in touch with the Bureau of Science and Industry in regard to matters which affected the mining industry. He said the Institute was within its rights in asking for representation on any Royal Commissions appointed by the Government in connection with the mining industry. Recently a commission was appointed, and the Institute did not approach the Government with a view to representation. He thought they should move in the matter.

The Chairman said Mr. Clayton had put a couple of very pertinent questions before them. In connection with representation on Royal Commissions, he said that the Federal Council, when it was formed, could assist them in obtaining such representation.

In closing the meeting, the Chairman conveyed to Messrs. Radcliffe and Statton the thanks of members for their courtesy in showing the visitors over the Small Arms Factory that afternoon.

WEDNESDAY, 24TH AUGUST, 1921.

Leaving Lithgow at 9 a.m., members motored to Portland, a distance of 16 miles, for the purpose of inspecting the works of the Commonwealth Portland Cement Co. Ltd. There they were met by Mr. F. S. Symonds (general manager), Mr. F. Saville (works manager), and members of the company's staff, under whose guidance a thorough inspection was made of the quarries, dryer shed, raw mill, mixing-house, rotary kilns, cement mill, cement silos, power plant, laboratory, railways, etc. The party was entertained by the company at lunch, presided over by Mr. Symonds, who gave members a very hearty welcome. Mr. G. C. Klug very cordially thanked the company for its hospitality. A return was then made to Lithgow, and the 3.12 p.m. train boarded for Sydney.

THURSDAY, 25TH AUGUST, 1921.

At 9.15 a.m. a special tram conveyed members to the Australian Electric Steel Company's works, Mitchell-street, Alexandria, where an interesting morning was spent in viewing the manufacture of high-grade steel castings, forgings, and ingots in carbon and alloy steels, etc.

After lunch the party proceeded by the 1.25 p.m. train to Rhodes, and there inspected the white-lead, paint, and varnish works of Lewis Berger and Sons (Australia) Ltd. Here members were much impressed with the great attention paid to industrial hygiene.

The Institute dinner was held at 7 p.m. in the Burlington Cafe, George-street. Mr. G. C. Klug presided. The guests were the Hon. George Cann, Minister for Mines; Mr. W. J. Newbigin, President Institution of Engineers, Australia; Mr. D. F. J. Harricks, Chairman, Sydney Division Institution of Engineers; and Mr. F. B. Guthrie, Chairman N.S.W. Branch Australian Chemical Institute.

After an excellent dinner the toast of "The King" was loyally drunk, and the toast of "Our Fallen Comrades" was honoured in silence.

The Chairman then proposed "The Mining Industry." In choosing Mr. George Cann as Minister for Mines, he said, the Storey Government had chosen a man of practical experience, integrity, and ability. The Institute had not been disappointed in its trip to Sydney, for it had seen a number of the industries allied to mining. Australians would have to find means for increased production in order to repair the ravages of war. One way was in training the rising generation of technical men to make them as efficient as possible, that they might compete against the men of other countries. Secondary industries could not survive if the primary industries were killed. He was sure that in the Hon. George Cann the mining industry had a firm advocate and a conscientious administrator.

The Hon. George Cann, in responding, quoted figures showing the past greatness of the mining industry of the State, and said he was sure that mining had a glorious possibility before it. Strikes were a curse in every industry. The New South Wales Mines Department was doing what it could to help mining. The various industrial minerals were being given particular attention, and reports on a number of them were being prepared. Mr. E. C. Andrews was preparing a report on Broken Hill. The mining companies had contributed liberally to the cost of making that survey. It was obvious that prospecting must be carried out in a more scientific way than it had been in the past. There were large areas of wild and geologically unknown country in the State, but these were going to be thoroughly examined. An excellent seam of coal had lately been discovered on the Southern railway line. Efforts were being made to obtain a better type of safety lamp for coal mines, and he proposed to bring a Bill before Parliament at an early date for the improvement of working conditions in collieries. There was a profit of £65,000 on the Mines Department of New South Wales last year, and he wished that he could spend the whole of that profit for the next three years on helping the mining industry.

Mr. G. H. Blakemore proposed "Kindred Institutes," to which Messrs. W. J. Newbigin, D. F. J. Harricks, and J. B. Guthrie responded. In the course of his speech Mr. Harricks expressed great satisfaction that during the visit of the Australasian Institute of Mining and Metallurgy to Sydney a definite position had been reached with regard to the formation of an Engineering Council. The importance of the work of such a federation, he said, could hardly be exaggerated.

Mr. F. Danvers Power amused the party with several very humorous reminiscences of mining in Australia.

The toast of "The Chairman" was given by Mr. Wm. Poole and enthusiastically honoured.

Mr. Klug, in responding, expressed his pleasure at the privilege of presiding at the dinner and throughout the meeting, which, he said, was characterized by one of the most important events in the history of professional men in Australia—viz., the formation of a Federal Council representing the Institution of Engineers, the Australian Chemical Institute, and the Australasian Institute of Mining and Metallurgy.

FRIDAY, 26TH AUGUST, 1921.

A start was made from the Central Railway Station (Sydney) by the 8.20 a.m. train for Port Kembla in a special observation car provided by the Railway Commissioners. Upon arrival at Port Kembla the party was met by Mr. E. A. White, the manager of the Electrolytic Refining and Smelting Company of Australasia Ltd., Mr. Selby Davidson (assistant manager), Mr. Greenwood (manager, Metal Manufactures Ltd.), and other members of the staff of these companies. An inspection of the Electrolytic Refining and Smelting Company's works was made before lunch. Each visitor was supplied with a flow-sheet, by which the treatment of the ore from its reception in the yard to the refinery department could be readily traced.

Members were then entertained by the company at a splendid lunch in the town hall. After lunch the inspection of the Electrolytic Refining and Smelting Company's works was completed, under the guidance of Mr. E. A. White, Mr. Selby Davidson, Mr. S. C. Jones (engineer), Mr. H. Rickleman (refinery superintendent), and Messrs. S. Walmsley and P. Harvey (assayers).

The works of Metal Manufactures Ltd. were inspected, the following acting as guides :—Mr. H. P. Greenwood (manager), Mr. J. P. Caddy (assistant manager), Mr. F. Barnett (superintendent, cable factory), and Mr. J. B. Shaw (superintendent, tube-mill department). Here were seen the processes of manufacture of all classes of bare copper wire and cable, cotton-covered wire, rods, strips, and shaped sections, and solid drawn copper and brass tubes. The following summary of the points of interest in these works was supplied to each member of the party :—

"This company manufactures all classes of bare copper wire and cable, cotton-covered wire, rods, strips, and shaped sections, and solid drawn and copper and brass tubes. The copper used is obtained from the Electrolytic Refining and Smelting Co., who receive the blister copper mainly from the large copper mines of Australia, refine, and cast it into various commercial shapes.

"*Rolling Mill.*—The ordinary-sized wire-bar is 3½ in. sq. x 3 ft. long, and weighs about 140 lb. Larger wire-bars are sometimes used for special work, as the manufacture of trolley wire, etc. These bars are heated to a red heat and then passed through a series of rolls, which reduces them to about 700 ft. of ¼-in. diam. rod. This 'black rod' is pickled in acid to remove the scale, and then sent to the wire-drawing machines.

"*Tandems.*—These machines reduce the ¼-in. rod to wire down to .056 in. diam. by drawing it through a series of dies arranged to give a definite relative reduction to the size required. The product is either used as bare wire, stranded into cables, covered with cotton, or drawn into finer wires.

"*Cones.*—Here the wire from the tandems is further reduced to various sizes down to .018 in. diam. A wire-bar weighing 140 lb., when drawn into wire of this size, would measure over 25 miles in length.

"*Blocks.*—These machines are used for making special high tensile wire, as used for telephone lines, rectangular and square wire, and small sizes of strip, etc.

"*Drawbench.*—Rods, bars, strips, and special sections are made by drawing the copper through a series of dies on this machine.

"*Stranders.*—There are four stranding machines in operation ; a new 19-wire strander and a rope-laying machine are being installed. In this department all sizes of cables are manufactured, composed of 3, 7, 19, 37, 61, 91, or 127 wires of various gauges.

"*Bright Annealing Furnace.*—If the copper is required to be annealed without oxidizing the surface, it is passed through this furnace. An endless chain carries the copper through a water-sealed muffle filled with a reducing atmosphere, kept at a temperature of about 1000° Fahr.

"*Cotton Covering.*—In this department the wire or strip is covered with a single or double layer of cotton, as required. This material is used mainly in the construction of dynamos and motors.

"The solid copper billets obtained from the Electrolytic Refining and Smelting Company are about 4 ft. long, and vary in diameter from 2½ in. to 6 in. The brass billets cast in our own foundry are solid for 60/40 brass and hollow for other mixtures. The zinc used is obtained from the Electrolytic Zinc Co., Tasmania.

"*Billet Piercing.*—The copper and 60/40 brass billets are heated in a producer-gas furnace and then passed through the piercing machine, from which they come out as hollows, with a wall thickness of from ¼ in. to ½ in. On entering the machine the red-hot billets are gripped between two rolls, which rotate them rapidly, at the same time causing them to travel forward over a steel plug, which gives the required inside diameter to the hollow.

"*Tube Drawing.*—The hollows are now taken to the drawbenches, where they are drawn over plugs or mandrel bars and through dies until required diameter and wall thickness is obtained. The tubes are annealed after each pass, the number of passes varying in accordance with the size of tube and wall-thickness required. The diameter of tubes manufactured varies from 9 in. to ⅛ in., and the wall thicknesses from .5 in. to .02 in. All tubes are carefully inspected for flaws and subjected to hydraulic pressure before leaving the factory.

"*Tinning.*—For some purposes, such as milking machinery, tinned tubes are required, and these are made by dipping copper or brass tubes into a bath of molten tin and then wiping off the surplus metal.

"*Wire.*—One of the principal uses for bare copper wire is for telephone lines, and this company supplies the whole of the requirements of the Commonwealth for this material. Round wire is also supplied for many and varied purposes, as small power-transmission lines, piano manufacture, and general hardware purposes.

"Trolley wire of different sections is supplied for railway and tramway systems. Square wire is made for nail manufacturers and rectangular wire for the manufacture of belting, etc.

"*Bars, Rods, and Strips.*—This form of copper is used for the construction of electrical machines, switchboards, and switch gear. Special sections are required for commutator bars, pantagraph strip, controller fingers and tips, etc.

"*Cables.*—Hard-drawn bare cable is supplied for power-transmission lines to councils, shires, power stations, mining and industrial companies, and State Departments.

"*Tubes.*—The principal consumers of copper tubes are the Railway Departments, who use the tubes in their locomotives. These tubes have to undergo very rigid tests before acceptance. Copper and brass tubes are also used for feed pipes, coils, and general hardware purposes. The most important use for brass tubes is for condensers, and the company supplies large quantities of tubes for this purpose."

The works of the Australian Fertilizer Pty. Ltd. were then inspected, under the guidance of Mr. A. J. Craig (works manager) and other members of the staff. Flow-sheets of the acid plant and of the superphosphate plant were provided.

A return was made by the 5.20 p.m. train to Wollongong, where again members met with another example of the hospitality of the Electrolytic Refining and Smelting Co. The whole party sat down to a sumptuous dinner. Mr. E. A. White, acting as host, expressed pleasure at the opportunity afforded him of welcoming members of the Institute and of meeting brother engineers and metallurgists from other parts of Australia.

Mr. G. C. Klug, in a suitable speech, acknowledged the compliment which the company had paid the Institute. His remarks were very heartily supported by every member of the party rising and giving the toast of "The Company" with musical honours.

A return was then made to Sydney, which city was reached at 10.23 p.m.

Saturday, 27th August, 1921.

Leaving Sydney by the 8.37 a.m. train for Burwood, and then taking a tram to Mortlake, members visited the works of the Australian Gaslight Company, of which Mr. H. Tindale is manager. Here an inspection was made of the gas works, tar-distilling plant, methods of handling coal from ships and on land, etc., Messrs. J. Dreverman (works chemist) and E. V. Capper (by-products chemist) acting as guides. A return to Sydney in time for lunch terminated one of the most successful and important meetings which the Institute has held.

OF THE EXECUTIVE COMMITTEE.

(Summary.)

JULY 18TH, 1921.—5 P.M. (Special Meeting).

A suggestion was submitted from the Broken Hill Branch that the Institute should conduct investigations with a view to bringing about the necessary improvements required in rock-drill steel which are now so much desired, to be in keeping with the great advance in rock-drilling machines. The cost of such investigation was estimated at £2000, and the time occupied about six months. The suggestion was adopted, and it was resolved that the Australian Metal Exchange be asked to give the financial support necessary to carry out the work.

A revised programme of the First Ordinary Meeting 1921 (Sydney) was submitted and approved. Directions were given regarding the issue of programmes and invitations.

Resolved that, as provided by the Articles of Association, a ballot be taken to decide which members of Council retire during 1921. It was decided that such ballot take place at a Special Meeting on Friday, 22nd inst., at 1 p.m., when the form of notice *re* election of President and Council would be decided upon.

JULY 22ND, 1921.—1 P.M. (Special Meeting).

A ballot was conducted to determine which members of the Council should retire during 1921. In conducting the ballot due regard was given to the representation each State was entitled to. As a result of the ballot the following were declared to be the retiring members:—Messrs. W. H. Corbould. Colin Fraser, H. W. Gepp, James Hebbard, H. Lipson Hancock, H. Herman, A. S. Kenyon. G. C. Klug. J. W. Sutherland, W. E. Wainwright, D. B. Waters, and George Weir.

Form of notice *re* election of President and Council was submitted and approved.

AUGUST 15TH, 1921.—8 P.M.

The Treasurer's report was presented, and showed that receipts since last meeting were—subscriptions, £97 4s.; interest, £9 7s. 6d

Accounts to the amount of £170, including advance expenses, Sydney meeting, £50; salaries and rent for May and June, £50; printing, £41; process blocks, £12; postage, etc., £13—were passed for payment.

Nominations as follow were approved :—As Member—Samuel George Turrell. As Associate Members—Dudley Sawtell Lawrence and Thomas Lindsay Wilson. As Junior—Carl August Schache. As Students—Max Roland Goldick, Theodore W. Tobe, Frank Watts, Cecil W. Wicks.

Resignation of A. Wauchope, on account of his having severed his connection with the mining industry, was accepted with regret.

Papers as follow were submitted and referred to the Publication Committee :—Concentrating Plant of the Broken Hill South Limited, by Messrs. W. E. Wainwright and T. A. Read; Investigations into Underground Efficiency, by Thos. G. Hanton; Determination of Minute Amount of Lead in Water, with Notes on Certain Causes of Erorr, by Messrs. David Avery, H. L. Hemingway, and V. G. Anderson and T. A. Read.

The resignation of Mr. F. W. R. Godden as local correspondent for Western Australia was accepted with regret, and his recommendation in regard to filling the position was referred to the Kalgoorlie Branch.

The Secretary was instructed in regard to making arrangements for a preliminary conference on the subject of the formation of an Engineering Council.

Progress was reported in respect to arrangements for the First Ordinary Meeting, 1921.

Resolved that, in the event of there not being a quorum of the full Council at the Sydney meeting, a business meeting of members be held to discuss certain subjects.

A report in regard to the proposal that the Institute conduct an investigation into the selection and treatment of drill steel was submitted, and decision deferred pending some satisfactory arrangement for financing the scheme.

It was suggested that an effort be made to secure employment for disengaged engineers, metallurgists, etc. It was considered that Institutes representing the various industries could render mutual assistance. Resolved that the matter be referred for discussion to the conference *re* Engineering Council.

SEPTEMBER 5TH, 1921.—8 P.M.

The Hon. Treasurer's report was submitted, and showed that receipts since last meeting totalled £44 10s. 9d.

Accounts to the amount of £54, including printing, £15, and legal advice, £32, were passed for payment.

The following were elected to the Institute:—As Member—Mr. Samuel George Turrell. As Associate Members—Messrs. Thos. Lindsay Wilson and Dudley Sawtell Lawrence.

A report of the First Ordinary Meeting, 1921 (Sydney), was submitted, and directions given regarding its inclusion in the Proceedings.

A recommendation from the Sydney meeting, that the First Ordinary Meeting, 1922, be held at Port Pirie, was submitted, and deferred for consideration till early in 1922.

A further recommendation from the Sydney meeting—viz., that the whole of the Commonwealth and New Zealand be organized into Branches—was submitted, and referred to a special sub-committee for report.

It was reported that the following nominations to fill the vacancies caused by the retiring President and Members of Council were received:—President—G. C. Klug. Council—Colin Fraser, W. E. Wainwright, A. S. Kenyon, and James Hebbard (Australasia); C. C. Freeman and F. Danvers Power (N.S.W.); H. Herman (Vic.); W. H. Corbould (Q.); H. Lipson Hancock (S.A.); J. W. Sutherland (W.A.); H. W. Gepp (Tas.); D. B. Waters (N.Z.)

Mr. H. A. Evans was appointed a member of Council in place of Mr. C. F. Courtney (retired).

Recommendations from the conference held in Sydney during the First Ordinary Meeting on the subject of the proposed Federal Engineering Council were submitted by the Institute's delegates. It was decided that copies of these recommendations be forwarded to all members of the Institute, with a recommendation that they vote for their acceptance. It was then resolved that an Extraordinary General Meeting be held on 28th November to examine the ballots.

Resolved that Universities and Schools of Mines be advised of the Council's decision to donate prizes of £10 for the best paper contributed by student-members in each State during 1921.

It was reported that two applications for Frecheville Fellowships had been received and forwarded to the Secretary of the Imperial College of Science and Technology.

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holiays.

MEMBERSHIP.

Since the issue of Proceedings No. 42 the following have been admitted to the Institute :—

Member.

Names and Addresses.

TURRELL, SAMUEL GEORGE, 13 Boulder Road, Kalgoorlie, W.A.

Associate Members.

LAWRENCE, DUDLEY SAWTELL, c/o Broken Hill Pty. Ltd., Newcastle, N.S.W.

WILLAN, THOMAS LINDSAY, Department of Mines, Sydney, N.S.W.

Junior.

SCHACHE, CARL AUGUST, Jung North, Vic.

Students.

GOLDICK, MAX ROLAND, 1 Somerset Place, Norwood, S.A.

TOBE, THEODORE WILLIAM, The University, Melbourne, Vic.

WATTS, FRANK, 14 Gillies Avenue, Haberfield, Sydney, N.S.W.

WICKS, CECIL WILLIAM, 3 Anderson Street, Marrickville, N.S.W.

FIRST ORDINARY MEETING, 1922.

A recommendation from the Sydney meeting, held in August last, that the First Ordinary Meeting, 1922, be held at Port Pirie, has been submitted to the Council, and an announcement thereon will be made early in 1922.

BRANCHES.

A recommendation was made at the First Ordinary Meeting, 1921, that a special effort be made to establish more Branches throughout Australasia. A special committee has been appointed to carry out this recommendation. The Council urges all members to assist in thus extending the work and usefulness of the Institute to all parts of Australasia.

FEDERAL ENGINEERING COUNCIL.

The following resolutions were adopted at a conference of delegates of the Australasian Institute of Mining and Metallurgy, Institution of Engineers (Australia), and the Australian Chemical Institute, held in Sydney on 22nd and 25th August:—

(1) That a Federal Council be formed by representatives of the Institution of Engineers (Australia), the Australian Chemical Institute, and the Australasian Institute of Mining and Metallurgy, hereinafter referred to as the constituent bodies, and that the name of the Council shall be "The Federal Engineering Council, Australia." Subject to the unanimous approval of the Councils of all the constituent bodies, other Federal Technical Institutions may be admitted to membership.

(2) That the objects of the Council shall be to consider and act upon matters of common concern to the technical professions and to co-ordinate the activities of the bodies represented on all questions of national and general importance.

(3) That the Council shall consist of three representatives from each of the constituent bodies, such representatives to be elected annually.

(4) That the Council shall elect a President from amongst its members, and shall appoint such officers and make such rules for the conduct of its business as may be found necessary. The Council shall elect its President within month of taking office.

(5) That the headquarters of the Council shall be Sydney.

(6) That the Council shall have no jurisdiction over the internal affairs of any constituent body, but its decision upon matters referred to it for decision by the whole of the constituent bodies shall be adopted by all such bodies.

(7) That the Council shall meet to deal with any question which may be referred to it by any constituent body, and in any case shall meet at least once annually. Where a representative is unable to attend any meeting of the Council, the constituent body that he represents shall have power to appoint a substitute for that meeting.

(8) That notice of any question referred to the Council by one of the constituent bodies must be forwarded to the Secretary of each of the other constituent bodies at least one month before the meeting of the Council at which the question is to be discussed; this period may be varied only with the consent of all the constituent bodies.

(9) That the constituent bodies shall meet the cost of the Federal Council in equal proportions, and it is considered that the contribution should not exceeed £25 per annum from each constituent body. The travelling expenses of delegates shall be met by their respective institutions.

(10) That any constituent body may withdraw from the Council by giving twelve months' notice, and after the expiry of that period it shall be relieved of all further obligations to the Council.

These resolutions have been forwarded to members in Circular No. 5, 1921, for ballot, with a recommendation that they vote in favour of adoption.

STUDENTS' PRIZES, 1921.

The Council has decided that during 1921 prizes of £10 will be awarded to student members in each State, subject to the following conditions:—

1. The competition shall be open to students who are at present members of the Institute or who may join during 1921.
2. The subjects on which essays may be written include Mining, Metallurgy, and Geology.
3. Papers may be illustrated, but the illustrations must be original—*i.e.*, not copies from existing ones.
4. The manuscript, with any drawings, etc., should be posted to reach the head office of the Institute not later than 31st January, 1922.
5. Papers will be examined and the award made by a committee of three gentlemen appointed by the Council of the Institute.
6. Each paper must be signed by a *nom de plume* only, the author's name and address to be enclosed in a separate envelope.
7. The prizes will consist of books or instruments to be selected by the authors of the successful papers.

PUBLICATIONS.

Papers appearing in this issue are:—

PAPERS—Notes on Tungsten, with Particular Reference to King Island Scheelite Treatment and Assays of Low-grade Material. By Herbert Lavers.

Ventilating Metalliferous Mines: a Method of Attack. By Thos. G. Hanton.

Determination of Minute Amounts of Lead in Water, with Notes on Certain Causes of Error. By D. Avery, A. J. Hemingway, V. G. Anderson and T. A. Read.

Description of New Plant at South Mine, Broken Hill. By W. E. Wainwright and J. C. Cunningham.

DISCUSSION—Mechanical Methods of Allaying Dust (P. H. Warren).

Written contributions to the discussion on these papers are invited.

ELECTION OF PRESIDENT AND COUNCIL.

As nominations received to fill vacancies caused by the retiring President and members of Council (as per Circular No. 4) do not exceed the number required, the following are elected, and take office from 1st January, 1922:—

President.—G. C. Klug.

Council.—Australasia—Colin Fraser, James Hebbard, A. S. Kenyon, and W. E. Wainwright.
N.S.W.—C. C. Freeman and F. Danvers Power.
Victoria.—H. Herman.
Queensland—W. H. Corbould.
South Australia—H. Lipson Hancock.
Western Australia—J. W. Sutherland.
Tasmania—H. W. Gepp.
New Zealand—Professor D. B. Waters.

FRECHEVILLE RESEARCH FELLOWSHIPS.

As in 1920, the Imperial College of Science and Technology, South Kensington, London, has again offered two Research Fellowships of £300 a year each to aid in carrying out any investigation or research connected with mining, mining geology, metallurgy, or the technology of oil. The Australasian Institute of Mining and Metallurgy represents the Imperial College in this matter. Two applications were received before the closing date—viz., 1st September—and were forwarded to London.

MOVEMENTS OF MEMBERS.

H. C. Bellinger (past President), recently at Chuquicamata, Chile, is now at 120 Broadway, New York.

Clement Dixon left Rhodesia in December, 1920, and is now in London. His address is—C/o. Standard Bank of South Africa Ltd., 10 Clements Lane, Lombard Street.

Cyril J. Emery, manager of the British Mine, Broken Hill, has returned from a visit to London and America.

James Hill notifies his change of address from Many Peaks to "Hilston," Brooloo, Queensland.

Eric W. Hughes is now on the staff of the South Australian School of Mines, Adelaide.

W. H. Johnston is again with the Waihi G.M. Co., Waihi, N.Z.

W. G. Langford, Local Correspondent of the Aus. I.M.M. for Papua, and Commonwealth representative on the Papuan Oilfields, has been appointed Manager in Papua for the Anglo-Australian Oil Company.

Arthur Moline, General Manager of the Bendigo Amalgamated Goldfields Ltd., has returned to Bendigo after visiting Europe, America, and South Africa.

John W. Moule (Member of Council), recently with the Burma Mines Ltd., has returned to Australia.

H. Hardy Smith is now in Sydney, having recently returned from Korea.

Dr. F. L. Stillwell, for some years Geologist to the Bendigo Amalgamated Goldfields Ltd., has left Australia to tour the South African goldfields, America, and Europe.

Revel Tinworth is now on the staff of Lewis Berger and Sons (Australia) Ltd., Rhodes, Sydney.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY

From 30th June, 1921 to 30th September, 1921.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
New South Wales Board of Trade : Report on Rural Industries and Rural Living Wage, 1921		Sydney
University of Sydney : Calendar for 1921		Sydney
Institution of Engineers, Australia (Adelaide Division) : The Torrens Road, by D. V. Fleming		Adelaide

Department of Mines, Western Australia :	
"Report on the Whim Well and Mons Cupri Copper Mines" by T. Blatchford	Perth
Institution of Mining Engineers :	
Transactions, Vol. LX., Parts 4 and 5 ; Vol. LXI., Parts 1—3	London
Institution of Mining and Metallurgy :	
Bulletins, Nos. 200—d	London
Geological Society :	
Quarterly Journal, No. 305	London
Societa Geologica Italiana :	
Bulletins, XXXVIII., Part 3	Rome
Annales des Mines :	
Vol. XI., Parts 4—7	Paris
Société des Ingeneiurs Civils de France :	
Bulletins, Oct. 1920 to March 1921	Paris
Mining and Geological Institute of India :	
Transactions, Vol. XV., Parts 2 and 3	Calcutta
Geological Survey of India :	
Records, LI. Parts 3, 4 ; LII. (1921) ; LIII. Part 1	Calcutta
Department of Mines, Canada :	
Summary Report Geological Survey, 1919 Part A, 1920 Parts B and E	Ottowa
American Institute of Mining and Metallurgical Engineers :	
Mining and Metallurgy, Nos. 174—176	New York
Department of Mines, Mexico :	
Boletin Minero Vol IX., Nos. 5 and 6 ; Vol. X., Nos. 3-6 ; Vol. XI., Nos. 1 and 2	Mexico

RECENT ARTICLES ON MINING MATTERS.

(30th June, 1921 to 30th September, 1921).

NOTE.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c., due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Bulletins*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng., New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

GEOLOGICAL.

The Origin of Primary Ore Deposits. J. D. Kendall. (35) May, 1921.
Nigerian Geology. J. D. Falconer. (35) June, 1921.
Replacement Copper Deposits in the Warren District. G. J. Mitchell. (6) Aug. 13, 1921.
Determining Dip of Vein at Depth. (6) Aug. 13, 1921.

MECHANICAL.

Air Receiver Calculations. W. S. Weeks. (6) June 11, 1921.
The Alvarado Type Ore-Skip. (6) July 2, 1921.
Rollsright Car-Tipple. A. G. Reese. (8) June 25, 1921.
Repairing a Wood-Stave Pipe-Line. G. A. Joslin. (8) July 30, 1921.
Improvements in Nodulizing at Chrome. C. L. Colbert. (6) Aug. 13, 1921.
Inverted Siphon Tap for Matte Settler. J. H. Gillis. (6) Aug. 20, 1921.
A Cheap and Efficient Rod-Mill Lining. M. S. Presler. (6) Aug. 20, 1921.

METALLURGICAL.

Development of the Rod Mill. E. H. Robie. (6) May 28, 1921.
The Engels Copper Mine and Mill, California. G. J. Young. (6) May 28, 1921.
Drying Fine Concentrates. (6) May 28, 1921.
The Smelter of the Calaveras Copper Co. E. H. Robie. (6) June 11, 1921.
The Metallurgy of Tungsten. (6) June 25, 1921.
Safety Attachment to Arsenic Condenser. H. Schwerin. (6) June 25, 1921.
The Effect of Sizing a Copper Blast-Furnace Charge. J. H. Gillis. (6) July 30, 1921.
Cyanide Notes. A. Del Mar. (8) June 11, 1921.
New Surface Plant for the United Verde Copper Co. L. A. Parsons. (8) June 25, 1921.
Determination of Zinc by the Potassium–Ferrocyanide Method. E. Oliver. (8) July 9, 1921.
Chloride Volatilization Process. T. Varley and C. C. Stevenson. (8) July 30, 1921.
Electric Muffle Furnaces for Laboratory Use. H. C. Kremers. (43) June, 1921.
A New Type of Electrolytic Cell. H. S. Lukens. (43) June, 1921.
Distillation of Oil Shale. D. E. Day. (8) Aug. 20, 1921.
The Volatilization Process at the Pope-Shenon Mine. R. H. Bradford. (8) Aug. 20, 1921.
The Role of Acid and Slimes in Flotation. B. H. M'Leod. (6) Aug. 6, 1921.
Is Moist Air Desirable for Copper Blast Furnaces? J. H. Gillis. (6) Aug. 13, 1921.
How to Test Platinum in Ores. (6) Aug. 13, 1921.
Metallurgical Progress in Shasta County, Cal. G. J. Young. (6) Aug. 20, 1921.

MINING.

Underground Haulage for Mines of Moderate Size. G. B. Rosenblatt. (8) June, 4 1921.
Blasting with Liquid Air. (8) June 18, 1921.
Notes on Open-Cut Mining. R. S. Botsford. (35) May, 1921.
Stope Measuring at the Passagem Mine of the Gold Mines of Ouro Preto Ltd. E. P. Caddy. (26) May, 1921.
Third Report of the Committee on "The Control of Atmospheric Conditions in Hot and Deep Mines." J. P. Rees. (26) Vol. XXI., Part 3.

MISCELLANEOUS.

The Kata Thermometer. (6) June 18, 1921.
Churn-Drilling of Disseminated Copper Deposits. E. R. Rice. (6) Serial commenced June 25, 1921.
The South African Gold Premium. (6) July 2, 1921.
Manufacture and Uses of Tungsten. W. E. John. (8) June 25, 1921.
Iron and Steel Industry of India. J. C. Brown. (35) Serial commenced June, 1921.
The Kata Thermometer and Its Practical Use in Mining. H. J. Ireland. (Reply to Discussion.) (28) May, 1921.
Notes on Some Useful Alignment Charts. J. A. P. Gibb. (26) May, 1921.
Graphite Industry in the United States and Canada. B. L. Miller. (6) Aug. 6, 1921.

PROCEEDINGS

OF THE

AUSTRALASIAN

Institute of Mining & Metallurgy

(INCORPORATED).

NEW SERIES.

No. 44.

EDITED BY THE SECRETARY.

This Institute is not responsible, as a body, for the facts and opinions advanced in any of its publications.

31st DECEMBER, 1921.

PUBLISHED QUARTERLY BY THE AUSTRALASIAN INSTITUTE OF
MINING & METALLURGY (INCORPORATED), MELBOURNE.

Australasian Institute of Mining and Metallurgy

(INCORPORATED).

LIST OF OFFICERS, 1921.

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Vice-Presidents:

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COLIN FRASER, S.A.

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RICHARD HAMILTON	Western Australia
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D. L. STIRLING, Melbourne, Vic.

BRANCH SECRETARIES:

Sydney	F. DANVERS POWER, 33-39 Hunter Street, Sydney, N.S.W.
Kalgoorlie	S. G. TURRELL, 13 Boulder Road, Kalgoorlie, W.A.
Broken Hill	C. H. J. CLAYTON, c/o Zinc Corporation Ltd., Broken Hill, N.S.W.
Mount Morgan	B. G. PATTERSON, Mount Morgan, Q.

LOCAL CORRESPONDENTS:

South Australia	H. W. GARTRELL, The University, Adelaide.
New Zealand	D. B. WATERS, Dunedin.
Tasmania	RUSSELL M. MURRAY, Mount Lyell.
North Queensland	MURRAY RUSSELL, Brisbane.
Papua	W. G. LANGFORD, Oilfields, Papua.

The Executive Committee consists of all Members of the Council residing, or for the time being, in Melbourne.

Head Office:

48 QUEEN STREET, MELBOURNE, VICTORIA.

Institute Matters.

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MINUTES OF MEETINGS.

OF THE INSTITUTE.

EXTRAORDINARY GENERAL MEETING, 28TH NOVEMBER, 1921.

AN Extraordinary General Meeting of the Institute was held at the rooms, 48 Queen-street, Melbourne, at 8 p.m. on Monday, 28th November, 1921, for the purpose of examining ballots on the question of the proposed Engineering Council, as submitted to members in Circular No. 5, 1921.

Mr. G. C. Klug, vice-president, occupied the chair.

The Secretary read the notice convening the meeting.

The scrutineers appointed by the Chairman to examine ballot papers reported the result of the ballot as follows:—

In favour of suggestions	198
Against ,, ...	1
Informal	1

OF THE EXECUTIVE COMMITTEE.

(Summary.)

October 31st, 1921.—8 p.m.

The Secretary's report was presented, and accounts to the amount of £191, including printing (£96), salaries and rent, two months (£50), postage (£25), sundries (£9) were passed for payment.

Nominations of the following were approved for ballot by members of Council:—As Members.—Messrs. E. C. Andrews, J. K. Campbell, and R. A. Clinton. As Associate Member.—Mr. Wm. C. Davies. As Student.—Mr. G. F. H. M'Mahon (elected). Nominations of Mr. Samuel Leah (as Member) and Mr. P. H. O'Nians (as Associate Member) were deferred for further particulars.

Resignation of Mr. Wm. Wylie was accepted.

Resolved that a memorandum be prepared for the guidance of local correspondents and local secretaries governing qualifications for the status of each class—*i.e.*, members, associate members, &c.

Resolved that the Institute of Science and Industry be requested to prepare an index of mining and metallurgical literature, and to keep same up to date; that copies of the index be supplied to the Institute.

Resolved that, when recommended by the Publications Committee, "galley pulls" of papers likely to provide useful discussion be circulated, and that Branch Secretaries or a member in each centre be appointed to secure discussion from such centres.

It was resolved that the members be reminded that the registration of members in the Institute employment register was purely voluntary, and was to be entirely left to the discretion of members. It was reported that all mining companies in Australasia had been invited to communicate with the Institute when positions were offering.

A memorandum from the Research Council to the President in regard to the proposed Federal Geological Survey was considered and the opinion expressed that the proposed salary of the Chief of the proposed Bureau was altogether inadequate. A similar opinion was expressed in regard to the salaries of the field geologists and travelling expenses. The Committee expressed itself in favour of the establishment of a Federal Geological Survey, and it was pointed out that such a survey had been urged by the Australasian Institute of Mining and Metallurgy in 1911.

Examiners were appointed to examine papers submitted by students for the Danks prize, 1921.

Correspondence was considered in regard to a proposal to secure a list of works on mining and metallurgy in the public libraries of the capital cities of Australia, and regret was expressed that the Institute had neither the funds nor the staff necessary to prepare a satisfactory index.

Other routine business was transacted.

NOVEMBER 28TH, 1921.—8.15 P.M.

The Secretary's report was presented, and accounts to the amount of £79 19s. 10d., including salary and rent, September and October (£50), printing, stationery, etc. (£22 9s. 6d.), postage and sundries (£7 10s. 4d.), passed for payment.

Nomination of Mr. I. B. Fabrikant as an Associate Member was approved for ballot.

The following were admitted to the Institute:—As Members—Messrs. E. C. Andrews and J. K. Campbell; as Associate Member—Mr. Wm. C. Davies; as Student—Mr. Ivan Fisher.

Resignation of Mr. K. Nakamura was accepted.

The Chairman reported that, as a result of the ballot at the Extraordinary General Meeting convened by Circular No. 5, 1921, the recommendations *re* proposed Federal Engineering Council had been accepted by members almost unanimously.

It was resolved that, as the recent Premiers' Conference could not deal with the question of certification of mining managers, the Secretary for Mines, N.S.W., be invited to convene a conference of the chief mining inspectors of the various States with a view to bringing about uniformity of examinations and reciprocity between States, also to deal with the question of engine-drivers underground being required to hold certificates.

Resolved, that the invitation from the Institution of Engineers to members of the Australasian Institute of Mining and Metallurgy to attend the meeting of the former, to be held in Melbourne on 31st January to 4th February, 1922, be accepted, and that members be notified.

Decided that copies of the memorandum on the question of engineering standardization received from the Institution of Engineers be supplied to members of Council, with a request for comment thereon.

Resolved that a letter be written to the Hon. the Minister for Mines, Victoria, directing his attention to prospectuses recently issued, particularly in respect to oil ; that the Minister be informed that the Council is strongly of opinion that prompt action should be taken by the Department of Mines to put the facts, as far as they can be ascertained, before the public. The Chairman was authorized to interview the Attorney-General in the matter.

It was reported that a clause in the Architects' Registration Bill, Victoria, safeguarding the interests of members of the Institute, and suitably providing for an engineering representation on the board, had been passed by the Legislative Council.

Papers as follow were submitted and referred to the Publication Committee :—" Notes on the Estimation of Tungsten in Ores," by J. R. Pound ; " Crushing Tests with a Small Pebble Mill," by E. E. G. Boyd.

Resolved that the Annual General Meeting, 1922, to receive the Report of the Council and Balance-sheet for 1921, be held on 27th March, 1922.

The Chairman (Mr. G. C. Klug) reported that Dr. A. J. Lanza, of the Rockefeller Institute, had recently given a lecture before the Broken Hill Branch on the subject of mining hygiene in America. He (the Chairman) was present, and welcomed Dr. Lanza as a member of a kindred institute, and also on account of his present official position.

The following notice of motion was submitted :—" That mid-day meetings of the Executive Committee be resumed when the new rooms were occupied."

NOTICES.

The rooms of the Institute are open from 9 A.M. to 5 P.M. daily, except Sundays and Public Holiays.

MEMBERSHIP.

Since the issue of Proceedings No. 43 the following have been admitted to the Institute :—

Member.

Names and Addresses.

ANDREWS, ERNEST CLAYTON, Government Geologist, Department of Mines, N.S.W.

Transfer, Associate Member to Member.

CAMPBELL, JOHN KENNETH, Stannary Hills, North Queensland.

Associate Member.

DAVIES, WILLIAM CHARLES, Huntly, Auckland, N.Z.

Student.

FISHER, IVAN, 11 Stanley-street, Canterbury, Vic.

FIRST ORDINARY MEETING, 1922.

Nothing definite has yet been arranged in regard to the First Ordinary Meeting, 1922, but an announcement thereon will be made as soon as possible.

ANNUAL MEETING, 1922.

As announced by Circular No. 6, 1921, the Annual Meeting to receive the Annual Report of Council and Balance-Sheet for 1921 will be held on Monday, 27th March, 1922. A meeting of the full Council will be held on the same day.

PROPOSED FEDERAL ENGINEERING COUNCIL.

A meeting of delegates from the Australasian Institute of Mining and Metallurgy Incorporated, the Institution of Engineers (Australia), and the Australian Chemical Institute will be held in Melbourne on 2nd February to take further steps in regard to the formation of the proposed Federal Engineering Council. As reported by Circular No. 6, 1921, members of the Aust. I.M.M. are in favour of the recommendations which were given in detail in Proceedings No. 43.

ENGINEERING STANDARDIZATION.

The Australasian Institute of Mining and Metallurgy will be represented at a conference to be held in Melbourne on 3rd February next to discuss the question of Engineering Standardization in Australia, the desirability of adopting British standards where possible, and the establishment in Australia of a representative and authoritative body to take the work in hand.

PUBLICATIONS.

Papers appearing in this issue are :—

PAPER.—" Concentrating Practice of the Broken Hill South Limited." By W. E. Wainwright and T. A. Read.

DISCUSSION.—" Mechanical Methods of Allaying Dust." By P. H. Warren. Author's final reply to discussion.

A. T. DANKS PRIZE, 1921.

T e " A. T. Danks Prize " for the best paper by a student descriptive of the Institute visit in August last to Sydney, Lithgow, Portland, and Port Kembla has been awarded to G. T. H. M'Mahon, of the Sydney University.

SUBSCRIPTIONS, 1922.

Members are reminded that subscriptions for the year 1922 are now due.

BRANCH NOTICES.

BROKEN HILL BRANCH.

A meeting of the Broken Hill Branch was held at the rooms of the Mine Managers' Association, Broken Hill, on Tuesday, 25th October, 1921, at 8 p.m.

Mr. C. C. Freeman (Chairman) presided.

Registration Index forms were distributed, and members requested to fill them in and forward them to the head office of the Institute. It was suggested that the Index Registration forms merely be the index to the ledger of technical qualifications; that the nomination forms be posted in the ledger, and that the history of each member since election be periodically brought up to date.

Mr. Eric E. G. Boyd replied to discussion on his paper, "Crushing Tests with Small Pebble Mill."

Mr. A. G. Campbell then contributed a paper giving a short description of operations at the Burma Corporation's mines.

On Thursday, 17th November, 1921, Dr. A. J. Lanza, of the International Health Board, Rockefeller Foundation, and now attached to the Commonwealth Department of Health, gave a lecture before the Branch at the Technical College, Broken Hill, on "Mining Conditions in the U.S.A." In the course of his lecture Dr. Lanza referred to the absence in the U.S.A. of legislation to prevent miners dry-boring. In addition to the use of water, he considered that good ventilation was the chief reliance to properly combat the dust evil. In the U.S.A. there was no compensation for sufferers from silicosis or any tuberculous complaint. He was very much impressed with the Clifton apparatus, which he saw in operation in the South mine, Broken Hill, and was of the opinion that its introduction into America might help in solving some of their dust problems. In America the U.S. Bureau of Mines had divided the country into districts, and each district had a mine rescue car (railway) completely equipped with the necessary apparatus, and each carried a staff consisting of a mining engineer, a physician, foreman miner, and first-aid man. The car visited the mines in its district alternately, and gave rescue and first-aid instructions to men and officials. In his experience he found the Proto oxygen apparatus preferable to others. He was strongly opposed to artificial breathing or resuscitation devices, as they are dangerous, especially in the hands of inexperienced or excitable persons, but considered the Schafer method of resuscitation the better way. Various sanitary systems were in use in American mines, some very simple and others quite elaborate ; the chemical closet seemed to be meeting with favour, and depended on a strong solution of caustic soda to dissolve the contents and render them unobjectionable. Rock temperatures in deep mines were sometimes quite high—as high as 100° or more. Canvas, or similar flexible tubing for carrying air to working places, was found to be most useful and economical. He was greatly impressed with his visit to Broken Hill mines, which were ahead of U.S.A. mines in preventing and controlling dust.

A meeting of the Branch was held at the rooms of the Mine Managers' Association on Tuesday, 13th December, 1921, at 8 pm.

Mr. C. C. Freeman (Chairman) presided.

It was resolved that it be a recommendation to the Council to adopt the suggestions in regard to Index Registration Forms as per circular recently issued by the Branch to members at Broken Hill.

The questions of the establishment of a library and the indexing of mining literature were discussed.

Mr. Salter tendered his notes on Dr. Lanza's lecture, delivered on 17th November.

Mr. P. Hampton Warren read his final reply to discussion on his paper, "Mechanical Methods of Allaying Dust."

MOVEMENTS OF MEMBERS.

E. C. Andrews, Government Geologist, New South Wales, has been elected honorary permanent secretary of the Australasian Association for the Advancement of Science.

Leslie Bradford, until recently metallurgist to the Broken Hill Proprietary at Newcastle, has started business at Waterloo, N.S.W. He has installed an electric furnace, and is making alloy steels and special castings.

H. Wheeler Brown, for many years engaged on the designing and constructional staffs of leading mines at Broken Hill, Kalgoorlie, and North Queensland, has started practice as consulting mechanical engineer at 434 Collins-street, Melbourne. Whilst at the front as O.C. of Section 3rd Aust. Tunnelling Company, Capt. Brown erected and ran a central workshops, and tested and reported upon mechanical appliances for use in the Tunnelling Companies of the First Army B.E.F., acting directly under the Controller of Mines, H.Q. First Army.

PERCY BURBIDGE, formerly on the staff of the Mount Elliott mine, Selwyn, North Queensland, is now in Melbourne.

H. EDWARD CLAYTON, who has for some time been on the staff of the Burma Mines Ltd., Burma, has returned to Australia, and is now at Homebush, N.S.W.

I. B. FABRIKANT has returned to Melbourne after two years with the Anaconda Copper Mining Co., Great Falls, U.S.A.

H. HERMAN (member of Council), engineer-in-charge of briquetting and research to the Victorian Electricity Commission, has returned from a nine months' trip abroad, undertaken for the principal purpose of investigating briquetting processes.

T. H. HOOPER has been appointed general manager of the Mount Royal Copper Mines, Tottenham, N.S.W.

G. FRED. JAKINS is now engineer-in-charge of the Mount Lyell Co.'s mines. Prior to this appointment he was the company's chief surveyor.

L. G. KLEM, formerly of Noumea, New Caledonia, is now in Sydney. His address is 19A Elizabeth-street.

CARL LINZ is with the Phœmco Co., Ltd., 4 Bridge-street, Sydney.

EDRIC N. MULLIGAN has been appointed manager of the Nawng Pet Tin Mining Co. Ltd., Taiping, Perak, F.M.S.

RUSSELL M. MURRAY is now assistant general manager of Mount Lyell Mining and Railway Co. Ltd. He has for a number of years occupied the position of engineer-in-charge of the mines.

H. J. ROBERTSON, late of Marion Bay Gypsum Works, Marion Bay, S.A., has left Australia to take charge of operations at the Bibiani Gold Mines, Gold Coast, West Africa.

S. G. LE SOUEF has been appointed to a position on the staff of the Royal Mint, Melbourne.

A. S. TAYLOR is now assistant Government Geologist in the Geological Survey of Uganda.

OBITUARY.

GORDON L. A. DITCHBURN (Associate Member) died from typhoid fever at Ipoh, Federated Malay States, on 23rd October, 1921, at the age of 29. He was a graduate of the Working Men's College, Melbourne, in mining engineering. His first appointment was with the

Diamond Creek G.M. Co. (Vic.) as surveyor, assayer, and metallurgist. After leaving that company he was for twelve months mine surveyor and assayer at the Mount Cleveland Tin Mine (Tas.) He then was employed by the Ivanhoe Gold Corporation Ltd., Kalgoorlie, for three years as assayer, and resigned to accept an appointment with the Pahang Consolidated Co., Pahang, F.M.S., as assistant mine surveyor. This position he occupied for two years and nine months, resigning a year ago to accept the position of surveyor to the Yukon Gold Co., Ipoh, F.M.S. He was the eldest son of the late George Ditchburn (Dept. of Lands, Vic.) and Mrs. Ditchburn, of Sandringham, (Vic.)

WILLIAM H. HAYES died suddenly in Adelaide on 19th November, 1921, of internal hemorrhage. Until eighteen months ago he was on the staff of the Wallaroo and Moonta Mining and Smelting Co., his period of service with that company extending over 50 years. He was also a member of the American Institute of Mining and Metallurgical Engineers, and a justice of the peace.

LIST OF PUBLICATIONS ADDED TO THE LIBRARY
From 30th September, 1921 to 31st December, 1921.

Australian Mining and Engineering Review	monthly	Melbourne
Industrial Australian & Mining Standard	weekly	Melbourne
Engineering and Mining Journal	weekly	New York
Iron and Coal Trades Review	weekly	London
Mining and Engineering World	weekly	Chicago
Mining Magazine	monthly	London
Indian Engineering	weekly	Calcutta
Chemical News	weekly	London
South African Engineering	monthly	London
Journal of Industrial and Engineering Chemistry	monthly	Easton, Pa.
Society of Chemical Industry : Journal	bi-monthly	London
Chemical, Metallurgical and Mining Society of South Africa : Journal	monthly	Johannesburg
Franklin Institute : Journal	bi-monthly	Philadelphia
Institution of Mechanical Engineers : Journal	monthly	London
Chamber of Mines of Western Australia : Journal	quarterly	Kalgoorlie
The West Australian Mining, Building and Engineering Journal	weekly	Perth
Queensland Department of Mines : Government Mining Journal	monthly	Brisbane
Transvaal Chamber of Mines : Monthly Analysis of Gold Production		Johannesburg
Rhodesia Chamber of Mines : Report of Executive	monthly	Bulawayo
Victorian Department of Mines : Geological Maps, Mirboo and Budgeree		Melbourne
Royal Society of Victoria : Proceedings, Vol. XXXIV., Part I.		Melbourne
New South Wales Board of Trade : Report on White Lead as used in the Painting Industry		
Compendium of Living Wage Declarations and Reports, N.S.W.		Sydney

Royal Society of New South Wales :	
Journal and Proceedings, Vol. LIV. - -	Sydney
Queensland Department of Mines :	
Annual Report, 1920 - - -	Brisbane
South Australia Department of Mines :	
Review, No. 32 - - - -	Adelaide
Institution of Engineers, Australia (Adelaide Division) :	
Concrete Footings for Columns, by Prof. Chapman	
Design for Reinforced Concrete Bridges, by Bowman	Adelaide
West Australian Department of Mines :	
Bulletin, Nos. 79-81 - - -	Perth
New Zealand Institute :	
Transactions, Vol., LIII. - - -	Wellington
New Zealand Geological Survey :	
Fifteenth Annual Report of Geological Survey -	Wellington
Institution of Mining Engineers :	
Transactions, Vol. LXI., Part 4; Vol. LXII., Parts 1 and 2 - - - -	London
Institution of Mining and Metallurgy :	
Bulletins, Nos. 203-207 - - -	London
Geological Society :	
Quarterly Journal, Nos. 306, 307 - -	London
Geologists' Association :	
Proceedings, Vol. XXII., Parts 2-4 - -	London
Iron and Steel Institute :	
Journal, Vol. CIII., No. 1	
Carnegie Scholarship Memoirs, Vol. X. -	London
Imperial Mineral Resources Bureau :	
Reports on Tungsten, Manganese, Fluorspar, Talc, Coal, Coke and By-Products, Statistical Summary, (Imports and Exports), Barium Minerals, Phosphates - - -	London
Societa Geologica Italiana :	
Bulletins, XL., Parts 1, 2 - -	Rome
R. Accademia delle Scienze dell' Institute di Bologna :	
Rendiconto, Vols. XXI., XXII. and XXIII. -	Bologna
Société des Ingeneiurs Civils de France :	
Bulletins, Vol. XL., Parts 1, 2 -	Paris

Annales des Mines :
  Vol. XI., Part 8 ; Vol., XII., Part 9 - Paris
Société Geologique du Nord :
  Annales Vol., XLIII., 1914 ; XLIV., 1919 - Lille
Museé Teyler :
  Archives, Serie III., Vols III., IV.
  Catalogue, Vol. IV. (1904—1912) - - Haarlem
Mining and Geological Institute of India :
  Transactions, Vol. XVI., Part 1 - - Calcutta
Department of Mines, Canada :
  Production of Coal and Coke in Canada, 1920
  Geological Survey Report, Parts C and A
  Memoirs, No. 124 - - - - Ottowa
United States Geological Survey :
  Mineral Resources—1915, Part I, Nos. 9-14 ; Part II, Nos. 15, 21, 26. 1916, Part I, No. 5, Part II. Nos. 4, 5, 9, 12, 27, 28. 1917, Part I, No. 9 ; 1918, Part I, No. 29, Part II, No. 36. 1919, Part I, Nos. 6-8, 14, 16, 18, 19 ; Part II, Nos. 4-12, 20, 23-27. 1920, Nos. 1-3.
  Professional Papers—Nos. 97, 98 P.Q.; 102, 103, 108 D.F.G.L.; 120 A.C.
  Mineral Resources—1918, 1920.
  Annual Report of Director—1920.
  Bulletin—Nos. 631 ; 640-I ; 641-F ; 643, 646, 652, 653, 659 ; 660-I ; 674, 675, 682, 697, 702, 703, 706, 712, 714, 715-GIS. 716-DEF, 725-A to E, 726-B - - - New York
American Institute of Mining and Metallurgical Engineers :
  Journal, Monthly - - - - New York
American Society of Civil Engineers :
  Transactions, Vol. LXXXIV. - - New York
California State Mining Bureau :
  Seventeenth Report of State Mineralogist, 1920 - Sacramento
Geological Survey of Alabama :
  Bulletin, No. 24—Mica Deposits of Alabama - Alabama
Secretoria de Industria Y Comercio :
  Bulletin, Vol. XI., Nos. 5, 6 ; Vol. XII., Nos. 1-3 Mexico

Cuerpo de Ingenieros de Minas :
  Bulletin, Nos. 97 and 100
  Annales Del Congress Nacional De La Industria Minero, Vol. I., II., IV., V. and VI. - Lima
El Museo Nacional :
  Annales, Vol. XXIII., XXIX. and XXX. - Buenos Aires

RECENT ARTICLES ON MINING MATTERS.

(30th September, 1921, to 31st December, 1921).

NOTE.—*This list is prepared for the purpose of placing before members the titles of the more important papers appearing in the usual publications concerned with mining engineering, metallurgy, &c., due regard being had to Australasian requirements.*

LIST OF PUBLICATIONS.

References are given by the number prefixed to each publication in the attached list. Wk., weekly mth., monthly.

(1) *The Industrial Australian & Mining Standard*, Melbourne, Victoria, wk., 6d.

(2) *The Queensland Government Mining Journal*, Brisbane, mth., 6d.

(3) *Metallurgical and Chemical Engineering*, New York, mth., 25c.

(4) *The Mining Journal*, London, E.C., wk., 6d.

(5) *Mining and Engineering World*, Chicago, wk., 10c.

(6) *The Engineering and Mining Journal*, New York, wk., 15c.

(7) *The Colliery Engineer*, Scranton, Pa., U.S.A., mth., 20c.

(8) *Mining and Scientific Press*, San Francisco, Cal., wk., 10c.

(9) *Annales des Mines*, Paris, France, mth.

(10) *Publications*, Department of Mines, Melbourne, Victoria.

(11) *Publications*, Department of Mines, Sydney, New South Wales.

(12) *Publications*, Department of Mines, Adelaide, South Australia.

(13) *Publications*, Department of Mines, Brisbane, Queensland.

(14) *Publications*, Department of Mines, Perth, Western Australia.

(15) *Publications*, Department of Mines, Hobart, Tasmania.

(16) *Publications*, Geological Survey, Canada, Ottawa, Ontario.

(17) *Publications*, Bureau of Mines, Toronto, Ontario.

(18) *Publications*, Geological Survey of India, Calcutta.

(19) *Publications*, Geological Survey, U.S.A., Washington.

(20) *Publications*, Geological Survey, Alabama, Montgomery, Ala.

(21) *Publications*, California State Mining Bureau, Sacramento, Cal.

(22) *Reports* Aust. Assoc. Adv. Science, Sydney, New South Wales.

(23) *Transactions and Proceedings*, New Zealand Inst., Wellington, New Zealand.

(24) *Quarterly Journal*, Geological Society, London.

(25) *Bulletins*, Inst. Mining and Metallurgy, London, E.C.

(26) *Transactions*, Inst. Min. Eng., London.

(27) *Journal*, Canadian Mining Inst., Ottawa, Ontario.

(28) *Journal*, Chem., Min., and Met. Soc. of S.A., Johannesburg, Transvaal.

(29) *Transactions*, Am. Inst. of Min. & Met. Eng. New York City.

(30) *Proceedings*, Colorado Scientific Soc., Denver, Col.

(31) *Journal*, Franklin Inst., Philadelphia, Pa.

(32) *Australian Mining and Engineering Review*, Melbourne, Vic., mth., 6d.

(33) *Transactions*, Am. Soc. C.E., New York City.

(34) *Bulletins*, Société des Ingénieurs Civils, Paris.

(35) *Mining Magazine*, 819 Salisbury House, London, E.C., mth., 1s.

(36) *Publications*, Iron and Steel Institute, London.

(37) *Proceedings*, Inst. of Mech. Eng., London.

(38) *Publications*, Field Columbian Museum, Chicago, U.S.A.

(39) *Journal*, Mining Society of Nova Scotia, Halifax, N.S.

(40) *Transactions*, Mining and Geological Institute of India, Calcutta.

(41) *Publications*, Department of Mines, Wellington, N.Z.

(42) *Journal*, Chamber of Mines of West Australia, Perth.

(43) *Journal of Industrial and Engineering Chemistry*, Easton, Pa.

LIST OF ARTICLES.

GEOLOGICAL.

Applied Geology at Butte. T. A. Rickard. (8) Sept. 24, 1921.

Structure and Genesis of Some Tin-Lodes Occurring in the Cawhorne District of West Cornwall. H. B. Cronshaw. (25) Sept., 1921.

The Igneous Rocks of the Province of Huelva and the Genesis of the Pyritic Ore-Bodies. H. F. Collins. (25) Nov., 1921.

MECHANICAL.

Shop Operations and Repairs on Gold Dredges. F. A. Stanley. (8) Oct. 22, 1921.

Use of Scrapers Underground. L. Eaton. (8) Nov. 19, 1921.

Air-Lift in Theory and Practice. A. W. Allen. (8) Nov. 19, 1921.

Standardization of Rock-Drilling Machines. (6) Oct. 29, 1921.

Mine Blacksmith Shops. R. J. Day. (6) Oct. 15, 1921.

The Tailing Air-Lift of the Chino Copper Co. H. G. S. Anderson. (6) Nov. 19, 1921.

METALLURGICAL.

Concentration of the Ore, Nevada Consolidated Copper Co. A. B. Parsons. (8) Sept. 3, 1921.

The Smelter, Nevada Consolidated Copper Co. A. B. Parsons. (8) Sept. 17, 1921.

The Beginning of the Cyanide Process on the Rand. A. F. Crosse. (8) Sept. 17, 1921.

Producer Gas. Erle Huntley. (8) Sept. 24, 1921.

Smelting Practice in the Zimapan District, Mexico. R. B. Brinsmade. (8) Sept. 24, 1921.

Agitation in Flotation. F. G. Moss. (8) Oct. 1, 1921.

Development of Copper Precipitating Apparatus. J. Irving. (8) Oct. 15, 1921.

The Gold Bullion Mill and Cyanide Plant, Willow Creek, Alaska. O. A. Glaeser. (8) Oct. 29, 1921.

Lime Consumption by Cyanidation. R. W. Perry. (8) Oct. 29, 1921.

Surface-Tension in Flotation. A. W. Fahrenwald. (8) Nov. 5, 1921.

Errors in Mine-Sampling. M. Webber. (8) Nov. 5, 1921.

Agitation in Flotation. A. W. Fahrenwald. (8) Nov. 19, 1921.

Time Studies in Metallurgical Analysis. W. F. Dietrich. (8) Nov. 19, 1921.

Surface Energy and Absorption in Flotation. A. W. Fahrenwald. (8) Aug. 13, 1921.

Treatment of Zinc–Silver Ore. A. Del Mar. (8) Aug. 20, 1921.

Distillation of Oil-Shale. D. E. Day. (8) Aug. 20, 1921.

The Volatilization Process at the Pope-Shenon Mine. R. H. Bradford. (8) Aug. 20, 1921.

Distribution of Gold as Banket Ore Classified Products, with Reference to Milling and Cyaniding Operations. F. Wartenweiler. (28) June, 1921.

A *Resume* of Standard Methods in Sampling, Analysis, and Classification of Coal. A. T. Williams. (28) July, 1921.

The Kata Thermometer and its Practical Uses in Mining. H. J. Ireland. (28) Aug., 1921.

A Simple Method for the Determination of Vanadium in Ores and Metallurgical Products. (43) R. B. Schaal. Aug., 1921.

Washing and Washing Ports in Connection with "Chamber" and "Frame" Filter Presses. E. A. Alliott. (43) Nov., 1921.

Filter Cloth and its Relation to Filtration. A. A. Campbell. (43) Nov., 1921.

Industrial Filter Media. A. Wright. (43) Nov., 1921.

Fundamental Laws of Filtration, with Suggestions Regarding Research Work. D. R. Sperry. (43) Nov., 1921.

The Feeding of Filters. J. F. Springer. (43) Nov., 1921.

Filter Acids. C. P. Derleth. (43) Nov., 1921.

The Use of Filter-Cel for Industrial Filtration Processes. G. M. Hickey. (43) Nov., 1921.

Centrifugal Filters. H. C. Beckman. (43) Nov., 1921.

Discussion of Centrifugal Draining. T. A. Bryson. (43) Nov., 1921.

Leaf and Rotary Suction Filters. G. D. Dickey. (43) Nov., 1921.

Plate and Frame Filter Presses. E. C. Alford. (43) Nov., 1921.

Modern Leaf Type Filters. R. C. Campbell. (43) Nov., 1921.

Oliver Continuous Filters. H. A. Morrison. (43) Nov., 1921.

The Atkins–Shriver Automatic Filter Press. H. D. Atkins. (43) Nov., 1921.

Vallez Rotary Filter. H. A. Vallez. (43) Nov., 1921.

Preliminary Roughing Concentration by Sorting, Jigging, and Tabling. E. S. Wiard. Serial commenced Aug. 27, 1921.

Inaccurate Assay Reports. G. L. Sheldon. (6) Aug. 27, 1921.

Recent Applications of the Cottrell Processes. R. B. Hesson, P. E. Landolt, and A. A Heimrod. (6) Sept. 17, 1921.

A Blast Furnace for Zinc. E. W. Buskett. (6) Sept. 10, 1921.

The Electrolytic Recovery of Zinc in Tasmania. (6) Sept. 24, 1921.

Smelting Sulphur and Arsenic Ores in China. R. Slessor. (6) Oct. 20, 1921.

Converting Dolomite into Magnesite. D. Eyoul. (6) Oct. 15, 1921.

Chloridizing Volatilization: Some Experiments and Their Practical Application. H. R. Layng. (6) Nov. 12, 1921.

History of Sile-Charging Reverberatory Furnaces. (6) Nov. 26, 1921.

Reclaiming 6-oz. Silver Tailing at the Coniagas Mines. H. E. Cawley. (6) Dec. 3, 1921.

MISCELLANEOUS.

The Magnetometer as an Aid in the Development of Mines. A. Gibson. (8) Sept. 24, 1921.

Scheduling Mine Operations to Suit a Power Current. B. B. Beckett. (8) Oct. 15, 1921.

Ventilation in Metal Mines. D. Harrington. (8) Oct. 29, 1921.

Breaking the World's Record in Shaft-Sinking. W. Fitch. (8) Nov. 26, 1921.

The Education of a Mining Engineer. T. A. Rickard. (8) Dec. 10, 1921.

Ventilation and Phthisis. C. L. Berrien. (8) Aug. 13, 1921.

Standardization of Materials in Mining and Milling Plant. E. A. Wraight. (25) Aug., 1921.

Ventilation and Human Efficiency. L. Hill. (25) Oct., 1921.

The Acidity of Mine Waters. F. W. Watson. (28) Sept., 1921.

Coal Pillar Extraction from Two Seams, and Surface Effects. W. T. Heslop. (28) Oct., 1921.

Waste in Ore Milled. W. A. Caldecott. (28) Oct., 1921.

A Review of Drilling. G. J. Young. (6) Serial commenced Aug. 27, 1921.

Licensing of Mining Engineers. (6) Sept. 3, 1921.

Mine Sampling Methods at Tyrone. B. G. Anderson. (6) Oct. 1, 1921.

Decay of Timber in Return Air Courses. D. Harrington. (6) Oct. 8, 1921.

Drilling Results and Dredging Returns. C. W. Gardner. (6) Serial commenced Oct. 22, 1921.

The Inorganic Origin of Petroleum. H. W. Hixon. (6) Oct. 15, 1921.

The Discrepancy between Drilling and Dredging Results. R. S. Smith. (6) Nov. 19, 1921.

Geological Methods of the Homestake Mining Co. (6) Dec. 3, 1921.

GUIDE TO CONTRIBUTORS OF PAPERS.

It is requested that writing be confined to *one* side of the paper ; that it be legible with particular care regarding foreign words; and that abbreviations, references, &c., be made in accordance with the subjoined rules and examples:—

Pounds, shillings, and pence, £ s. d. ; dollars and cents, $, c.
Grains, gr., pennyweights, dwt. ; ounces, oz. ; drachms, dr. ; pounds, lb.
Quarters, qr ; hundredweights, cwt.; gallons, gal.
Grammes, grm. ; kilogrammes, kg. ; millimetres, mm.; milligrammes, mg.
Centimetres, cm. ; cubic centimetres, cc. ; metres, m.
Inches, in. ; feet, ft. ; yards, yd. ; fathoms, fath.
Square inches, etc., sq. in. ; cubic inches, etc., cub. in.
Diameter, diam.; revolutions, rev.; revolutions per minute, r.p.m.
Horse power, h.p.; indicated horse power, i.h.p.; brake horse power, b.h.p.
Candle power, c.p.
British thermal units, B.Th.U.
High pressure, H.P. ; low pressure, L.P.
Ampere, amp.: kilowatts, kw.
Percentages, %; degrees, ° ; specific gravity, sp. gr.
Company Limited, Co. Ltd. ; and Company, & Co.
Temperatures to be given in Fahrenheit, thus : 10° Fahr.

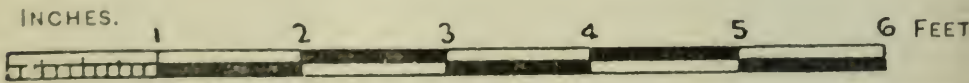
Figures not exceeding four, unless in column with others exceeding four, to be without comma, thus : 1907.

References to be placed in foot-notes, giving title in italics, thus : *Alfred James. *Cyanide Practice*, p. 94 : † H. Brown. *Mines and Minerals*, vol. xiii., p. 130; ‡ *Trans Aust. Inst. M.E.*, vol. x, pp. 98-189.

Quotations to be indicated by inverted commas, and when lengthy, to be set in smaller type, with inverted commas at beginning and end only. Foreign terms to be in italic.

Localisms to be in inverted commas with their ordinary technical definition in parenthesis.

Drawings (on tracing cloth if possible), photographs (unmounted glossy-surface bromides) or other glossy-surface prints, &c., both for exhibition and for publication, are most desirable with almost every communication, and should always be on separate paper from the MS. Blue-prints only to be forwarded when original plans or tracings are not procurable. When reference letters are used in drawings for purposes of description, they are best thus : *a b c*, etc. Lettering and figuring on drawings should be large to allow of reduction to page size whenever possible. All lines should be black and firm. Each drawing should be accompanied by scale thus :—



N.B.—When in doubt about any point, it would be advisable to communicate with the Secretary.

COMPANIES ACT 1915.

MEMORANDUM

AND

ARTICLES OF ASSOCIATION

OF THE

Australasian Institute of Mining and Metallurgy (Incorporated).

⁂

MELBOURNE:
ARNALL & JACKSON, PRINTERS, 478 COLLINS STREET.
1921.

COMPANIES ACT 1915.
No. 2631, Section 24.

Certificate of Incorporation.

This is to certify that "Australasian Institute of Mining and Metallurgy (Incorporated)" is this day incorporated under the Companies Act 1915 and that the Company is limited by guarantee.

Given under my hand at Melbourne this Seventh day of April, 1921.

J. EDWARDS,
Deputy Registrar-General.

SEAL.

MEMORANDUM OF ASSOCIATION

OF THE

Australasian Institute of Mining and Metallurgy (Incorporated).

I. The name of the Association is the "AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY (Incorporated)."

II. The Registered Office of the Institute shall be situated in the State of Victoria.

III. The Objects for which the Institute is established are:—

(*a*) To acquire and take over the whole or any of the assets and liabilities of the unincorporated Australasian Institute of Mining and Metallurgy.

(*b*) To promote the welfare and advancement of the mining and metallurgical industries in all or any of their branches, and all matters connected with or relating to the production of minerals.

(*c*). To promote and facilitate the interchange of information, ideas, and practice, on all matters pertaining to mining and metallurgy; to watch over, promote, and protect the mutual interests of the members and to provide facilities for promoting and maintaining professional intercourse among them by means of meetings, discussions and papers, and to publish and issue same.

(*d*) To watch, and, if necessary, take action in public matters incident to the mineral industry by making representations to the Legislatures, public departments, and others; by seeking improvements in the law and its administration by petitioning Parliament and by taking such other steps and proceedings as may be deemed expedient in the interests of the public and the Institute.

(*e*) To promote technical education in connection with mineral industries.

(*f*) To encourage original research in matters connected with the mineral industry.

(*g*) To watch over the general working conditions and to protect the welfare of all those engaged in the mining and metallurgical industry.

(*h*) To promote just and honorable practice in the profession of mining and metallurgical engineering, management and administration, and to suppress malpractices.

(*i*) To establish Branches and Divisions for the promotion of all or any of the objects of the Institute and to make regulations or by-laws governing the same.

(*j*) To secure the establishment and maintenance of a register of mining engineers and metallurgists duly qualified to practise as such in Australasia.

(*k*) To take steps to ensure that the prospectus of every new mining or metallurgical enterprise, intended for public subscription, shall be supported by a report from a qualified mining engineer or metallurgist who is registered according to clause (*j*).

(*l*) To secure and maintain as far as possible uniformity of mining legislation in the different States and New Zealand.

(*m*) To encourage and promote the geological survey of the Commonwealth of Australia and the Dominion of New Zealand, and their systematic prospecting on scientific lines.

(*n*) To urge upon the Government of the Commonwealth or of any of the Australian States or the Dominion of New Zealand the desirability of having on any Royal Commission, committee, or court of inquiry appertaining to the production of minerals, a member or adviser who is registered in accordance with clause (*j*) as a duly qualified mining engineer or metallurgist.

(*o*) To purchase, acquire, hire or lease any freehold or leasehold property for the purposes of the Institute, and to improve, alter and develop the same by the erection of any buildings thereon or otherwise, and generally to utilize such property to the best advantage, and to sell, lease, place under option or otherwise dispose of any such property or any assets or effects of the Institute for such consideration and upon such conditions as the Institute may think fit.

(*p*) To raise or borrow money in such manner and upon such terms and securities as the Institute shall think fit and to secure the repayment thereof in any way, and in particular by the issue of debentures or debenture stock or by giving mortgages, charges or securities charged upon or over all or any of the Institute's real and personal property, both present and future, and to purchase, pay off or redeem any such securities.

(*q*) To invest any moneys of the Institute in such investments or securities, or in such manner as the Institute may think expedient.

(*r*) To procure the Institute to be legalized, domiciled, recognized or registered in any other State of the Commonwealth of Australia or in the Dominion of New Zealand or any other country or place.

(*s*) To do all such other things as may appear to be conducive to the attainment of the above objects or any of them.

IV.—The income and property of the Institute, whencesoever derived, shall be applied solely towards the promotion of the objects of the Institute as set forth in this Memorandum of Association, and no portion thereof shall be paid or transferred, directly or indirectly, by way of dividend, bonus or otherwise howsoever by way of profit to the members of the Institute. Provided that nothing herein contained shall prevent the payment in good faith of remuneration to any officers or servants of the Institute or other person not being a member of the Institute in return for any services actually rendered to the Institute, the carrying out or giving effect to any of the objects comprised in or referred to in Clause III. of this Memorandum, or the payment of railway or other fares to members or persons attending Council or Committee meetings, or the payment in good faith of the out-of-pocket expenses of delegates appointed by the Council to attend the meetings of other institutions or bodies as representatives of the Institute.

V. Paragraph IV. of this Memorandum is a condition on which a licence is granted by the Attorney-General to the Institute in pursuance of section 27 of the "Companies Act 1915."

VI. If any member of the Institute pays or receives any dividend, bonus, or other profit in contravention of paragraph IV. of this Memorandum, the liability of every member of the governing body of the Institute who has concurred in or authorized such payment shall be unlimited, and the liability of every member of the Institute who has received any such dividend, bonus or other profit as aforesaid shall likewise be unlimited.

VII. Subject to the last preceding paragraph, the liability of the members is limited.

VIII. Every member of the Institute undertakes to contribute to the assets of the Institute in the event of the same being wound up during the time he is a member or within one year afterwards for payment of the debts and liabilities of the Institute contracted before the time at which he ceased to be a member, and of the costs, charges and expenses in winding up the same, and for the adjustment of the rights of the contributories among themselves such amount as may be required not exceeding £1, or, in case of his liability becoming unlimited, such other amount as may be required in pursuance of paragraph VI. of this Memorandum.

IX. If upon the winding up or dissolution of the Institute there remains, after the satisfaction of all its debts and liabilities, any property whatsoever, the same shall not be paid to or distributed among the members of the Institute but shall be given or transferred to some Association or Associations having Objects similar to the Objects of the Institute, to be determined by the members of the Institute at or before the time of dissolution and in default thereof by such judge of the Supreme Court as has or acquires jurisdiction in the matter.

We, the several persons whose names and addresses are subscribed hereto, are desirous of being formed into an association in pursuance of this Memorandum of Association.

NAMES, ADDRESSES AND DESCRIPTIONS OF SUBSCRIBERS.

ROBERT WILLIAM CHAPMAN,
Professor of Engineering,
The University of Adelaide.

GEORGE CHARLES KLUG,
Mining Engineer,
360 Collins Street, Melbourne.

WILLIAM EDWARD WAINWRIGHT,
Mining Engineer,
360 Collins Street, Melbourne.

GEORGE WEIR,
Mining Engineer,
360 Collins Street, Melbourne.

COLIN FRASER,
Mining Engineer,
Collins House, Melbourne.

Dated the 18th day of March, 1921.

Witness to all the above signatures other than that of Robert William Chapman—

DAVID LAUDER STIRLING,
Secretary,
48 Queen Street, Melbourne.

Witness to the above signature of Robert William Chapman—

HERBERT WILLIAM GARTRELL,
Lecturer on Mining Engineering,
Adelaide University, S.A.

ARTICLES OF ASSOCIATION

OF THE

Australasian Institute of Mining and Metallurgy (Incorporated).

PRELIMINARY.

1. In these Articles, unless there be something in the subject or context inconsistent therewith—

"Institute" shall mean the Australasian Institute of Mining and Metallurgy (Incorporated).

"Minerals" shall include all useful metalliferous and non-metalliferous minerals, including coal and mineral oils and also metals and their compounds.

"Mining" shall include mining geology, and "Metallurgy" shall include metallurgical chemistry.

"State" shall include each State of the Commonwealth of Australia and the Dominion of New Zealand.

"The Register" means the register of members to be kept in accordance with Section 32 of the "Companies Act 1915."

"Month" means calendar month.

"The office" means the registered office for the time being of the Institute.

"In writing" means written, printed, or typed, or partly written and partly printed or typed, and includes lithography and any other substitute for writing.

Words importing the singular number only include the plural, and vice versa.

2. In these Articles "member" shall, except where the subject or context clearly indicates that such term is used to indicate a person belonging to a particular grade of membership or a member of the Council or any committee, or where the term is used in conjunction with the words "Associate" or "Corporate" or otherwise, where the subject or context will not so permit, be deemed to include all persons becoming or elected members of any of the grades of membership hereinafter referred to.

3. For the purposes of registration, the number of members of the Institute is declared not to exceed six hundred. The Council may, whenever it thinks fit, register an increase of members.

ORGANIZATION.

4. Branches may be formed throughout the Commonwealth of Australia and the Dominion of New Zealand, with the approval of the Council, upon the request of a sufficient number of corporate members.

5. Whenever it may appear expedient, members resident in any State of the Commonwealth or in New Zealand may be organized by the Council into a Division in order to more effectually carry out all or any of the objects of the Institute in the States of the Commonwealth concerned or New Zealand.

6. The Council shall have power to appoint a local correspondent, in places where there is no Branch, whose functions shall be to keep the Council informed on local mining conditions affecting the Institute and to investigate and advise the Council on any matter of local importance which may be submitted to him.

MEMBERSHIP.

7. The Institute shall consist of Members and Associate Members who shall be Corporate Members; and of Juniors and Students.

8. All Members, Associate Members and Students of the unincorporated Australasian Institute of Mining and Metallurgy automatically become members of the same class of membership in the Institute on incorporation, on payment of arrears, if any, due to the unincorporated Australasian Institute of Mining and Metallurgy.

9. All Members, Associate Members, Juniors and Students shall be equally entitled to the privileges of membership, provided that Juniors and Students shall not be entitled to vote or act as officers.

10. Any Member, or Associate Member, having occasion to designate himself as belonging to the Institute, shall state the grade to which he belongs according to the following abbreviated forms respectively: M. Aus. I.M.M., A. M. Aus. I.M.M.

11. MEMBERS.—Every candidate for election or transfer into this grade shall be at least thirty (30) years of age, and shall have been engaged in practising his profession in some section of Mining or Metallurgy for at least twelve (12) years, during which period he shall have occupied a responsible position in the design, construction, management or operation of important work or plant for at least five (5) years, and shall have acquired some degree of eminence in the profession. He shall further satisfy the Council that he has received a good general and technical education or training. The term of twelve (12) years may, at the discretion of the Council, be reduced to ten (10) years in the case of a candidate who has graduated at a Mining School recognized by the Council, or who has passed such other examination as in the opinion of the Council is considered sufficient. Teachers of Mining or Metallurgy recognized by the Council shall be considered as practising their profession.

12. ASSOCIATE MEMBERS.—Every candidate for election or transfer into this grade shall be at least twenty-five (25) years of age and shall produce

evidence to the satisfaction of the Council that he has been trained as a mining engineer or metallurgist, and has been engaged in the practice of his profession for at least four (4) years, excluding apprenticeship, pupilage or training, provided such term shall be deemed satisfactory by the Council. In the case of graduates of Mining Schools, recognized by the Council, the term of four years may be reduced to three years. Every candidate shall pass an Associate Membership examination before a Board of Examiners appointed by the Council, but he may be exempted if—

(*a*) He has already passed an examination which, in the opinion of the Council, is equivalent to the Associate Membership examination ; or

(*b*) Having attained the age of 30 years he can produce evidence that he has had, excluding apprenticeship, pupilage or training, at least eight years' experience, partly in the office and partly in or upon mining or metallurgical plant or work, provided that such experience shall be deemed satisfactory by the Council.

13. JUNIORS.—Every candidate for election or transfer into this grade shall be at least twenty-one (21) years of age and shall have been engaged in some section of Mining or Metallurgy for at least four (4) years, and shall have had such experience as will enable him to fill a subordinate position in Mining, Metallurgical or allied industries. The period of four years may be reduced to one year in the case of a candidate who has graduated in a Mining School recognized by the Council. Every candidate who is not a graduate from some Mining School recognized by the Council shall satisfy the Council that his general and technical education is up to the required standard. No person shall remain in the grade of Junior for more than ten (10) years from the time of his election or transfer.

14. STUDENTS.—Every candidate for election into this grade shall be at least seventeen (17) years of age. He must either be a student of some Mining School recognized by the Council or occupy some subordinate position connected with the practice or science of some section of Mining or Metallurgy. He shall satisfy the Council that he has received or is receiving training as Mining Engineer or Metallurgist, and has received or intends to obtain sufficient practical and scientific training to fit him for a responsible position in the Mining Industry. No person shall continue as a Student if he ceases to follow the profession, nor in any case after a period of six (6) years from election.

ADMISSION, TRANSFER, RESIGNATION AND EXPULSION.

15. Every proposal for admission as Member, Associate Member, Junior or Student, or for transfer from one grade to another shall be in accordance with a prescribed form on which, over the signature of the candidate, his name, age, usual residence and qualification, shall be distinctly stated and which shall contain an undertaking by the candidate, if elected or transferred, to conform to the Memorandum and Articles of Association of the Institute and any rules and regulations made by the Council.

16. Every proposal for admission to the grades of Member, Associate Member or Junior shall be signed by not less than three Corporate Members

each of whom must certify to personal knowledge of the candidate and a full conviction of his qualifications. In special circumstances, where the candidate cannot obtain three signatures of corporate members possessing personal knowledge, the Council may admit the candidate on production of satisfactory evidence as to qualification and character.

17. Every proposal for admission to the grade of Student shall be signed by the Principal or Instructor in Mining or Metallurgy of the Mining School in which the Student is studying, or by two Corporate Members of the Institute.

18. The proposal form when completed shall be forwarded to the Secretary who shall submit it to the Council for consideration.

19. The Council shall seek confirmation of and determine whether the qualifications of a candidate are in accordance with the Articles of Association of the Institute and, if so, may admit the candidate to the grade for which he is qualified.

20. All elections shall take place by ballot of Members of Council and, if the majority of the Council voting be in favour of the candidate, he shall be declared elected and shall be duly notified by letter of the fact by the Secretary.

21. Every person shall become a Member, Associate Member, Junior or Student of the Institute in the class to which he is elected, upon payment of his prescribed entrance fee (if any) and first annual subscription.

22. The Council may, in its absolute discretion, refuse to approve the application for admission or transfer of any applicant, and in the event of disapproval shall not be required to state or assign any reason therefor.

23. No rejected candidate for election shall be nominated again until a period of twelve months shall have elapsed since his rejection.

24. A member of any grade in the Institute may resign his membership by a written communication to the Secretary, which shall be accepted if all his dues and other indebtedness have been paid as provided by the Articles of Association.

25. The Council shall have the right by a majority of four-fifths of those who record their vote, provided that at least half the number of Council vote, to suspend or expel from the Institute any Member of any grade of the Institute who may be convicted by a competent tribunal of felony, embezzlement, larceny, or misdemeanour, or other offence or of any conduct which in the opinion of the Council renders him undesirable as a member; and in the case of the Council being of the opinion that the conduct of any member of any grade of the Institute is such as warrants it being the subject of enquiry with a view of ascertaining whether there are grounds for his suspension or expulsion; or in case ten or more Corporate Members shall think fit to draw up and sign a proposal for the expulsion of a member of any grade on any grounds whatever and shall deliver the same to the Secretary to be laid before the Council for consideration, the Council shall call upon the person so charged for an explanation and shall make such other enquiry as it deems adequate and if it does not find sufficient reason for suspension or expulsion no entry of the enquiry shall be made in the Minutes, but, if the Council by

a majority of at least four-fifths of those voting, provided at least half the number of Council vote, does find good reason for expulsion of the member on the ground that he has been guilty of disgraceful conduct in any professional respect, it shall direct the Secretary to address a letter to the person proposed to be expelled, requesting him to withdraw from the Institute. If he immediately withdraws from the Institute there shall be no entry in the Minutes nor discussion. If not complied with, the Council shall cause such person's name to be erased from the Register of the Institute, thus expelling him from the Institute. Due notice shall be sent by the Secretary to the expelled person.

26. The rights and privileges of members of any grade shall cease immediately upon their resignation or upon removal of a member's name from the Register of the Institute for any cause.

PROFESSIONAL CONDUCT.

27. Every member of the Institute shall observe and be bound by the following regulations:—

(*a*) He shall act in all professional matters strictly in their fiduciary manner with regard to any client whom he may advise, and his charges to such clients shall constitute his only remuneration in connection with such work, except as provided by section (*d*) of this Article.

(*b*) He shall not accept any trade commissions, discounts, allowances or any indirect profit in connection with any work which he is engaged to design or to superintend or with any professional business which may be entrusted to him.

(*c*) He shall not, while acting in a professional capacity, be at the same time a director or member of or a shareholder in or act as agent for any mining or metallurgical enterprise, contracting or manufacturing company or firm or business with which he may have occasion to deal on behalf of his clients, or have any financial interest in such business, without disclosing the fact in writing to his clients.

(*d*) He shall not receive directly nor indirectly any royalty, gratuity or commission on any patented or protected article or process used on work which he is carrying out for his clients, unless and until such royalty, gratuity or commission has been authorized in writing by those clients.

(*e*) He shall not improperly solicit professional work either directly or by an agent, nor shall he pay by commission or otherwise any person who may introduce clients to him.

(*f*) He shall not be the medium of payments made on his client's behalf to any contractor or business firm, unless specially so requested by his client, but shall only issue certificates or recommendations for payment by his client.

Any alleged breach of these regulations or any alleged unprofessional conduct by a member, which may be brought before the Council, shall be investigated and, if proved, shall be dealt with by the Council in accordance with Article 25.

SUBSCRIPTIONS.

28. Each Member on election shall pay an entrance fee of two guineas and an annual subscription of two guineas.

29. Each Associate Member on election or transfer from a lower grade shall pay an entrance fee of one and a half guineas and an annual subscription of one and a half guineas. On transfer from Associate Member to Member each Associate Member shall pay a transfer fee of half a guinea.

30. Each Junior on election shall pay an annual subscription of one guinea.

31. Each Student on election shall pay an annual subscription of one half guinea.

32. Annual subscriptions shall become due on the first day of January in each year, and any member whose subscription is twelve (12) months in arrears shall not be entitled to attend or participate in any meeting or business of the Institute until such subscription be paid.

33. Any member whose subscription is twelve (12) months in arrears shall be reported to the Council, who shall direct application to be made for the immediate payment of the same and, in the event of the subscription continuing in arrears for two months after the date of the said application, the Council shall have power to remove the name of the defaulter from the Register of the Institute. Provided that he may be restored to membership by the Council on payment of all arrears.

34. Any member, elected within three months preceding the commencement of a new year, shall, on payment of his annual subscription, be entitled to membership for the remainder of that year and the ensuing one, except that he shall not be entitled to the Proceedings of that year in the latter end of which he was elected.

35. The Council may, at its discretion, remit the annual subscription or the arrears of annual subscriptions of any Member or Associate Member who shall have been a subscribing member for not less than two years.

36. Any Member or Associate Member, whose subscription is not in arrears, may at any time compound for future annual subscriptions by the payment of twenty (20) guineas, if paid in any one of the first five (5) years of his membership. If paid subsequently the sum of twenty (20) guineas to be reduced by one-half guinea for every year of membership after five (5) years. In either case the composition subscription is inclusive of the ordinary subscription paid or payable in respect of the year in which he may compound.

THE COUNCIL.

37. The Council shall consist of not more than twenty-eight (28) members comprising a President, the past President who last held office and is willing to act, eight (8) ordinary members of Council to be elected by the whole of the Corporate Members, and sixteen (16) ordinary members to be elected by the States in proportion to the number of Corporate Members resident therein: no State to have less than one member of Council to represent it. Two of the ordinary members of Council shall act as Vice-Presidents. They shall hold office for two years or until their successors take office.

The first Council shall consist of Professors R. W. Chapman, E. W. Skeats, and D. B. Waters and Messrs. E. G. Banks, G. H. Blakemore, A. A. Boyd, John M. Bridge, Geo. H. Broome, W. H. Corbould, C. F. Courtney, G. D. Delprat, Colin Fraser, H. W. Gepp, Richard Hamilton, H. Lipson Hancock, James Hebbard, H. Herman, James Horsburgh, A. S. Kenyon, G. C. Klug, John W. Moule, Robt. C. Sticht, J. W. Sutherland, W. E. Wainwright, and George Weir, and they shall hold office until their successors are appointed as hereinafter provided. The Council may add to their number from time to time, having regard to the proportional representation of States, but so that their number shall not exceed the maximum number above fixed.

38. The President of the Institute shall be elected annually by the whole of the Corporate Members, but no one shall be eligible for the position for more than two consecutive periods.

39. One Vice-President shall be elected each year by the Council at its first meeting from among its own number, but such election shall not be deemed to create a vacancy in the Council.

40. One-half of the Councillors shall retire at the end of each calendar year except the year 1920. A retiring Councillor shall be eligible for re-election, and shall, unless he notifies his intention to withdraw, be deemed to be duly nominated for the office.

41. The one-half to retire at the end of the year 1921 shall (unless the Councillors agree among themselves) be determined by lot, having regard in the case of those selected by the State to the proportional representation of States. In every subsequent year the one-half who have been longest in office shall retire. As between two or more Councillors who have been in office an equal length of time, the Councillors to retire in any year shall, in default of agreement between the retiring Councillors, be determined by lot. The length of time a Councillor has been in office shall be computed from his last election or appointment.

42. Only persons of the grade of Member may be nominated for election to the Council.

43. The President and Councillors shall be elected in the month of November of each year by postal ballot, but shall not take office till the first of January of the following year.

44. Any Corporate Member may nominate a candidate for the position of President or Councillor provided that the nomination be supported by at least three other Corporate Members. The nomination, which must be in writing and endorsed by the person nominated, must be in the hands of the Secretary not later than 1st September of each year and the Secretary shall, not less than forty (40) days before the date fixed for the closing of the ballot, post to every Corporate Member a list of all nominations received, but shall not send the name of any person nominated who may be ineligible for election to such office.

45. If through any cause the office of President becomes vacant, the Council shall elect a successor from among the Vice-Presidents for the unexpired portion of the term; but this shall not affect his possible subsequent election under clause 38.

46. If, through any cause, the office of a Vice-President becomes vacant, a successor for the unexpired portion of the term shall be elected by the Council from among its own members.

47. If a sufficient number of nominations for the Council are not received, the Council shall make the necessary nomination or nominations.

48. Any member of Council who is unable to attend a full meeting of Council, as defined in clause 60, may nominate a member to act as his substitute, but the Secretary must be notified in writing before the meeting.

49. Any vacancy in the office of Councillor shall be filled by the Council for the unexpired portion of the term, due consideration being given to the State that the former Councillor represented.

50. Should a Councillor be unable to attend to his duties and fail to resign, or to obtain leave, the Council, after due warning, may appoint a substitute for the unexpired portion of the term, due consideration being given to the State that the Councillor represented.

51. It shall be the duty of the Council to provide for the proper conduct of the business of the Institute, and to provide every possible means for the advancement of the interests of the Institute and of the objects embraced within its scope.

52. Any difference of opinion arising with regard to the Memorandum or Articles of Association of the Institute or their interpretation shall be submitted to the Council, whose decision shall be final.

53. The Council shall have the right to make by-laws for the carrying out of the business of the Institute; provided such by-laws are in accordance with the Memorandum and Articles of Association of the Institute.

SECRETARY AND TREASURER.

54. A Secretary shall be appointed by the Council. His remuneration shall be determined by the Council and he shall hold office subject to removal by an affirmative vote of a majority of the members of Council.

55. It shall be the duty of the Secretary, under the direction of the Council:—

(*a*) to conduct the ordinary business of the Institute;

(*b*) to keep an accurate record of the proceedings of the Institute and of the Council;

(*c*) to keep a correct roll of members' names and addresses and dates of admission and transfer, this roll to be known as the "Register of the Institute";

(*d*) to collect the subscriptions and to keep correct accounts of expenditure and receipts;

(*e*) to conduct the correspondence of the Institute;

(*f*) to give notice of all meetings of the Council and general meetings of the Institute;

(*g*) to supervise the printing and to edit the publications of the Institute; and

(*h*) to perform any such other duties as the Council may determine.

56. There shall be an Honorary Treasurer, elected annually by the Council at its first meeting, who must be a Corporate Member residing in the locality of the headquarters of the Institute. If not a Councillor, he shall nevertheless attend the meetings of the Council and may take part in the deliberations but may not vote. He shall, subject to any expressed provision in the Memorandum and Articles of Association, perform any such duties as the Council may determine. The appointment of a Councillor to the position of Honorary Treasurer shall not be deemed to create a vacancy in the Council.

57. An Auditor, who shall be a public accountant resident in the locality of the headquarters of the Institute, shall be appointed at the Annual General Meeting and he shall be responsible for the audit of the accounts for the ensuing year. He shall have access, at all reasonable times, to the accounts of the pecuniary transactions of the Institute and shall verify and sign the annual statement of accounts before it is submitted by the Council to the Annual General Meeting. The Auditor's remuneration shall be approved by the General Meeting.

MANAGEMENT.

58. The location of the headquarters of the Institute shall be determined by the Council from time to time.

59. All the powers of the Institute and the management and control of its business and affairs shall be vested in the Council, who, in addition to the powers and authorities by these Articles expressly conferred upon them, may carry into effect all or any of the objects of the Institute mentioned in the Memorandum of Association, and may exercise all such powers and do all such acts and things as may be exercised or done by the Institute and are not hereby or by statute expressly directed or required to be exercised or done by the Institute in general meeting, and the Council shall generally direct the business of the Institute either itself or through committees.

60. There shall be at least two meetings of Full Council per annum and eight members of Council shall form a quorum. A Full Council meeting is one to which all members of Council or their nominees are summoned to attend.

61. The Council shall appoint an Executive Committee consisting of all Members of the Council resident, or for the time being, in proximity to the Head Office, three Members of which shall constitute a quorum. Routine business may be carried out by the Executive Committee, but matters of policy or important business must be submitted to all members of Council, and, except at a meeting of Full Council, shall be decided by postal ballot. Copies of minutes of all business transacted by the Executive Committee must be sent by the Secretary to the remaining members of the Council not more than three days after.

62. The Council may also appoint Standing Committees who shall retain office for a period of one year or until their successors shall be appointed. It may at any time appoint such other Committees as may be considered advisable. These Committees shall report to the Council and perform their duties under its supervision.

63. The Honorary Treasurer shall be ex officio a member of the Finance Committee which shall include at least three Members of Council.

64. The President shall be ex officio a member of every Committee appointed by the Council.

65. The affairs of every Branch and Division shall be administered under the direction of the Council and in conformity with the Memorandum and Articles of Association, and the committees to be appointed under the next two succeeding Articles shall exercise such powers as the Council may approve.

66. Each Division, when expedient, shall be managed by a Committee known as a Division Committee elected annually by and from the Corporate Members of that Division, and consisting of a Chairman, Committeemen and such other officers as may be deemed necessary. Each Branch in a Division shall have at least one representative on the Division Committee.

67. Each Branch shall be managed by a Committee known as a Branch Committee, elected annually by and from the Corporate Members of that Branch, and consisting of a Chairman and such other officers as may be deemed necessary.

68. No Committee shall publish or communicate to any party or parties who are not members of the Institute any matter which may purport to represent the policy of the Institute, or any Branch or Division without the expressed sanction of the Council.

69. Branches and Divisions shall, within two months of the termination of the financial year, forward reports and audited accounts to the Council.

70. The Council shall investigate any alleged or apparent irregularity or unconstitutional act of any Committee coming within its knowledge, and, if it thinks fit, shall call upon that Committee for an explanation thereof. If the explanation be deemed insufficient, the Council shall inquire further into the matter, and, if satisfied that a breach has been committed, it shall notify the offending body to that effect, and require compliance with the Rules. Should any Committee disregard such instructions, the Council may forthwith dissolve such Committee and appoint another Committee to carry out the duties for the unexpired term of office.

BRANCHES AND DIVISIONS.

71. A Branch may be authorized by the Council at the written request of sufficient Corporate Members living within an appropriate distance from a central point.

72. Only one Branch shall be authorized in one locality.

73. The Council shall define the territory of a Branch.

74. The Council shall have a right to cancel a Branch or re-adjust its territory.

75. Branches and Divisions shall have the right to make rules for its own government, subject to the approval of Council, and not inconsistent with the Memorandum and Articles of Association of the Institute. The Council shall have the right to amend, annul or add to these Rules.

76. The Council shall if required, and as far as practicable, contribute from its funds for the necessary running expenses of any Branch or Division, an amount in the former case not exceeding in any year twenty-five (25) per cent. of the funds received from the resident members of the territory belonging to the said Branch, but in no case to exceed the sum of fifty pounds (£50). which shall not be cumulative from year to year, but in cases where the Council considers it is under special obligations to do so, the amount paid may be increased to fifteen shillings (15s.) per member per annum. Requests for such appropriation shall be signed by the Chairman and Secretary of the Branch. If the expenses of a Branch exceed the appropriation made by the Council, the difference may be made up by voluntary contributions by the members of the said Branch. The Institute shall not be responsible for the debts of any Branch or Division.

77. A Secretary for each Branch and Division shall be elected annually by the corporate members of the Branch and Division.

BALLOTING.

78. Any important matter affecting the welfare or policy of the Institute shall be decided by secret postal ballot of all Corporate Members. A statement prepared by the Council giving the arguments for or against its adoption shall be sent to each Corporate Member together with a blank ballot paper.

79. Any ballot paper for candidates or questions to be decided shall be deemed invalid if the number of names or proposals remaining thereon shall exceed the number required.

80. The candidates elected or questions decided upon shall be those receiving the greater number of votes.

81. The voter shall strike out the names on the list of persons for whom he does not intend to vote or if it is a matter of " Yes " or " No " he shall strike out the word he does not agree with.

82. The ballot papers shall be opened and examined by two scrutineers, appointed by the presiding officer, who shall announce the results to him, who in turn shall report the results to the Council.

83. The ballot papers shall be destroyed after the results have been certified to by the scrutineers.

MEETINGS.

84. There shall be at least two (2) meetings of the Institute in the course of the year, viz. :—

(*a*) An Annual Meeting, and
(*b*) one or more Ordinary Meetings.

At least 80 days notice of Annual and Ordinary Meetings shall be sent to members by the Secretary.

85. The Annual Meeting shall be held in March in each year at the Headquarters of the Institute on such a day as shall be fixed by the Council.

86. The Annual Meeting shall be for the purpose of receiving and considering the report of Council and certified statement of accounts to the end of the preceding calendar year; for recording the results of ballots on questions for which votes of Corporate Members have been received by post, and for any other business dealing with the affairs of the Institute.

87. Ordinary Meetings of the Institute shall be held at such places and on such dates as may be determined by the Council. The quorum for an annual or ordinary meeting shall be eight members present in person.

88. At least one Ordinary Meeting shall be so arranged as to include visits of inspection to places of mining or allied interest as may be determined by the previous similar meeting or, in default, by the Council. The objects of the Meeting shall include—

(*a*) A Full Meeting of Council which shall review the activities of the Institute and shall deal with business submitted by the Branches and Divisions or by petition signed by ten (10) Corporate Members. Councillors shall as far as practicable be notified of such business. The Council shall also deal with such other business as it may see fit.

(*b*) The activities of the Institute and important matters of policy shall be presented to members and be open for discussion by members.

(*c*) To visit mines and works of interest.

(*d*) To read and discuss papers.

89. The Council may, at any time, call an Extraordinary General Meeting of Corporate Members at whatever place it may think fit, for a specific purpose relative to the direction and management of the concerns of the Institute or for any other purpose which it thinks necessary. The Council shall at all times be bound to do so on a requisition submitted by a Branch or by petition signed by not less than ten (10) Corporate Members. The notice calling an Extraordinary General Meeting shall distinctly specify the business to be brought before it and no other business than that specified shall be discussed. At least 14 days notice of such Extraordinary General Meeting shall be sent to members by the Secretary.

90. The President shall take the chair at all meetings of the Institute at which he is present. In the absence of the President the senior Vice-President shall preside ; but, in the case of the absence of the President and both Vice-Presidents, the meeting may elect any Member of Council or in the case of their absence any Member or Associate Member present to take the chair at the meeting.

91. The Executive Committee shall meet as often as the business of the Institute may require. In the absence of a quorum the meeting shall be adjourned for a period of one week, notice of such adjourned meeting being issued to members of the Executive and the business for which such meeting was adjourned may be dealt with by the members present at the adjourned meeting.

92. Each Corporate Member shall be entitled to introduce two visitors to any Ordinary Meeting of the Institute.

93. It shall be in the power of the Council to issue invitations to the Press and to gentlemen interested in any subject intended, or likely to be brought forward for consideration or discussion.

94. Visitors shall not take part in the proceedings without the consent of the Meeting.

PAPERS AND PUBLICATIONS.

95. The official record of technical papers and discussions shall be known as " The Proceedings of the Australasian Institute of Mining and Metallurgy " and shall be published by direction of the Council. There shall be included therein the Annual Report of the Council, the Statement of Accounts, Reports of Branches and Divisions, Reports of Technical Committees and business records of the Institute.

96. Every Member, Associate Member, Junior and Student whose subscription is not more than six (6) months in arrears shall be entitled to receive a copy of all the publications of the Institute.

97. No duplicate copies of the Proceedings nor any portion of them shall be issued to any of the members or others unless by permission of the Council.

98. The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and it shall be at liberty, when thought desirable, to direct that any paper read before the Institute or any abstract therefrom shall be printed in the Proceedings, and immediate notice shall be given to the author whether the paper is to be printed or not. If a paper is not accepted for publication by the Institute the author shall have the right to publish it elsewhere.

99. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings or in its Proceedings.

100. Arrangements regarding publications shall be in the hands of a Publication Committee to be appointed by the Council.

101. The copyright of all papers communicated to and accepted by the Institute shall be vested in it, unless otherwise agreed upon between the Council and the author, and such papers shall not be published for sale or otherwise without the written permission of the Council.

102. The authors of papers who are easy of access shall have an opportunity of personally revising their own communications before they are finally printed. All proofs must be returned within twenty-one (21) days of the date of postage by the Secretary, otherwise it will be considered that the author has no corrections to make.

103. The author of each paper read before the Institute shall be entitled to 25 copies, if printed, for his own use, free of cost and shall have the right to order any number of copies at the cost of paper and printing, provided the said copies are not intended for sale.

104. The Council may sell single copies of papers or Proceedings published by the Institute to members at prices not less than the actual cost of paper and printing with at least fifty (50) per cent. added.

105. The Council may dispose of single copies of papers or Proceedings to non-members of the Institute, not residing within Australasia, but the charge shall not be less than the cost of paper and printing with a hundred (100) per cent. added.

106. The Council may dispose of Proceedings to approved persons who wish to subscribe regularly on payment of two guineas per annum.

ADDITIONS OR AMENDMENTS TO ARTICLES OF ASSOCIATION.

107. Written notice of any proposed addition or amendment to the Articles of Association shall be sent to the Council.

108. The proposed additions or amendments shall be printed within ten days of their consideration by the Council, and copies forwarded to all corporate members within the Commonwealth of Australia and Dominion of New Zealand (who are not in arrears) at least forty (40) days before the day appointed for the holding of the first extraordinary meeting to consider the resolution for the amendment of the Articles.

109. The Secretary shall forward to each corporate member (who is not in arrears), with the notice convening the meetings to consider the special resolution for amendment of the Articles, a form of proxy for such corporate member to sign, and a voting paper whereon the corporate member may indicate in what manner he desires to vote at the said meetings.

110. The Secretary shall publish and distribute to members not later than the next distribution of printed matter, after the date of the confirmatory meeting, an announcement of the result of the meetings, together with a text of the amendments made to the Articles.

SEAL.

111. The Council shall provide for the safe custody of the common seal, and the common seal shall never be used except by the authority of the Council previously given and in the presence of one member of Council at least, who shall sign every instrument or document to which the common seal is affixed, and every such instrument and other document shall be countersigned by the Secretary or some other person appointed by the Council.

CHEQUES, BILLS, &c.

112. All cheques, bills of exchange, and promissory notes shall be signed, drawn, accepted, made, or endorsed, as the case may be, for and on behalf of the Institute by one member of Council at least, and countersigned by the Secretary or some other officer authorized by the Council, or shall be signed, drawn, accepted, made, or endorsed, as the case may be, on behalf of the Institute in such other manner as the Council may from time to time determine.

NOTICES.

113. A notice may be served by the Institute upon any member either personally or by sending it through the post in a prepaid letter addressed to such member at his registered or last known address. Any notice sent by post shall be deemed to have been served at the time when the letter containing the same would have been delivered in the ordinary course of the post, and in proving such service it shall be sufficient that the notice was properly addressed and put in the post office. Where it is proposed to pass a special resolution or special resolutions, the meetings may be convened by one and the same notice, and it shall be no objection that such notice only convenes the second meeting contingently on the resolution or resolutions being passed by the requisite majority at the first meeting.

SIGNATURES OF SUBSCRIBERS.

R. W CHAPMAN.

G. C. KLUG.

W. E. WAINWRIGHT.

G. WEIR.

COLIN FRASER.

Dated the 18th day of March, 1921.

Witness to all of the above signatures other than that of Robert William Chapman—

D. L. STIRLING.

Witness to the above signature of Robert William Chapman—

H. W. GARTRELL.

Papers and Discussions.

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A PROPOSED COPPER METALLURGICAL PROCESS.

BY P. BURBIDGE, A.S.T.C., Associate Member.

FOREWORD.

The writer had the pleasure of several months' laboratory tests on a metallurgical process for copper ores devised by Mr. W. H. Corbould, Consulting Engineer, North Queensland.

Mr. Corbould's research work in this direction commenced some six years ago, and he eventually succeeded in obtaining a good extraction of copper and a resulting solution practically free from iron and other impurities.

The commercial operation of the process was investigated and special machines with novel features were designed.

OUTLINE OF THE PROCESS.

The process described in detail in the following pages, requires for successful application that the ores contain at least the minimum ratio of sulphur to copper, consistent with the production of sulphatising roasting conditions.

[This paper is separately bound, and may be, if so desired, detached complete from this number.]

The essentials of the process are as follows :—

1. Fine grinding followed by a sulphatising roast.
2. Agitation with acid solution produced within the process by electrolysis.
3. Purification of a portion of the "mother liquor" and electrolytic deposition of the contained copper, thereby producing sufficient free sulphuric acid in solution for the next charge of calcine and further requirements as stated on pages 9 and 10.
4. Partial purification of the remaining "mother liquor" together with the first wash solutions and precipitation of the copper content as hydrate by milk of lime.
5. Dissolution of the copper in the hydrate precipitate by means of a solution of ammonia, followed by distillation of the ammonia liquor producing pure copper oxide and recovering the aqua ammonia by condensation.
6. Reduction of copper oxide to metallic copper.
7. Treatment of the residue from 5 for the production of a by-product and the recovery of any remaining copper.
8. Treatment of the washed slime residues from the ore charge for gold and silver by the cyanide process.
9. Use of producer water gas for the whole of the metallurgical operation as heating gas and to provide sulphate of ammonia.

The process is thus characterized by the production of electrolytic and best selected copper only, and where not absolutely self-contained, the cost of outside reagents is nullified. by the production of marketable by-products for use as fertilisers.

PREPARATION OF ORES.

Where ores of various chemical compositions are treated at one works, charges, based on chemical analysis for Cu, Fe, S, SiO_2 and acid-consuming minerals, are drawn from the different bins to the rock breaker, thence by conveyer to the revolving dryer, tramp iron being extracted en route by suspended electro-magnets.

The dried ore—through a four-inch ring—is crushed to one-inch size by a sheer crusher and finally, by a similar type of machine, is ground to 30 mesh, and is exhausted from the latter machine by a vacuum system to the roasting furnace bin.

The shear crusher and grinder, designed expressly for these conditions, namely fine dry grinding, is shown in Fig. 1.

With this machine the object is to obtain a true shearing action by means of two vertical discs revolving in opposite directions at different speeds, and also a choke effect making for large capacity with small wear on the disc liners.

Referring to Fig. 1, the self-feeding arrangement, air-cooling system and other details are clearly shown.

The adjustment for degree of fineness of product is readily made by means of a hand wheel operating the sliding thrust block shown in Fig. 1 (6).

Separate motors drive the two independent sections, the low-speed self-feeding section having a variable-speed motor to adjust the rate of feed which is dependent on the speed of the feed scoop. The pinion driving the low-speed section has a wider face than its corresponding spur wheel to give the lateral movement necessitated by the hand wheel adjustments.

The speeds of the feed and high-speed sections are respectively 200 and 2000 ft. peripheral per minute.

The machine is accessible, discs and liners being designed to be taken down and replaced with a minimum loss of time.

Means are providing for immediately holding fast the low-speed shaft in the case of failure of the driving belt. When grinding fine the two revolving discs have the advantage over machines with one fixed disc, that a screening action takes place giving greater capacity. Material sufficiently ground is rapidly discharged into the dust hood by centrifugal force.

The relatively small amount of wear on the liners means of course less cost of steel per ton of ore.

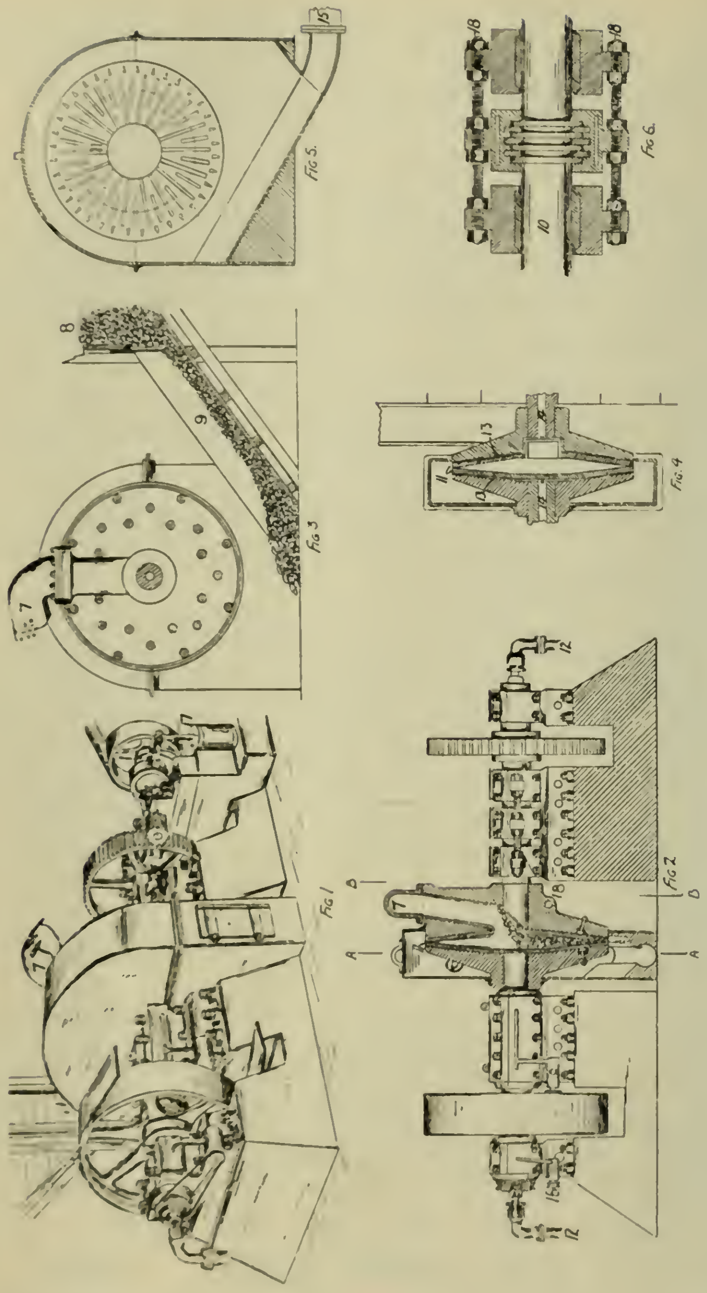

Fig. 1.
SHEAR CRUSHER.

FIG. 1.—REFERENCES.

1. Prospective view of shear crusher.
2. Longitudinal elevation, partly in section.
3. Transverse view on line BB of Fig. 2.
4. Sectional plan through the grinding mechanism, showing details of air service entry.
5. Transverse view on line AA of Fig. 2. showing shearing ribs on grinding liner.
6. Adjustable water-cooled thrust-block.
7. Feed scoop.
8. Ore bin.
9. Feed chute.
10. Hollow thrust shaft.
11. Manganese steel grinding liners.

12. Connections conveying air for cooling manganese steel liners.
13. Air vents at back of liners for cooling same.
14. Hollow shafts to convey cooling air.
15. Vacuum pipe to furnace bin.
16. Lubricating pump for oiling hollow thrust shaft.
17. Solonoid operated safety brake
18. Screws to take up wear of liners and provide necessary degree of crushing fineness.

ROASTING.

Amongst all the furnaces at present in use for sulphatising roasting, Mr. Corbould was unable to find one to fulfil all the requirements, muffle furnaces of the Wedge type being perhaps the nearest approach.

The essential requirements, temperature control and large capacity, demand a radical departure from existing types, and to obtain them the furnace shown in detail in Fig. 2 was evolved.

In the operation of this furnace, the ore charge is subjected to heat by radiation and conduction through the internal tube system, and at the same time to alternate pressure and exhaust through the filter boxes.

Referring to Fig. 2—the Corliss type gear is so arranged that a rapid change from pressure to exhaust or change of ratio of duration of pressure and exhaust can be effected by means of the adjustable duplicate cams.

This arrangement has great advantages in heating up the charge to the reaction temperature (about 560° C.) without the danger of over-roasting, and allows the charge to be maintained at the correct temperature during the time necessary to complete the calalytic action.

During the first stage of the roasting, the valves may be set to produce a gas rich in sulphur dioxide which, in the process described, will be compressed and stored for use in a later stage.

When sufficient gas has been thus obtained, the cams may be quickly adjusted whilst the furnace is in motion to introduce more air.

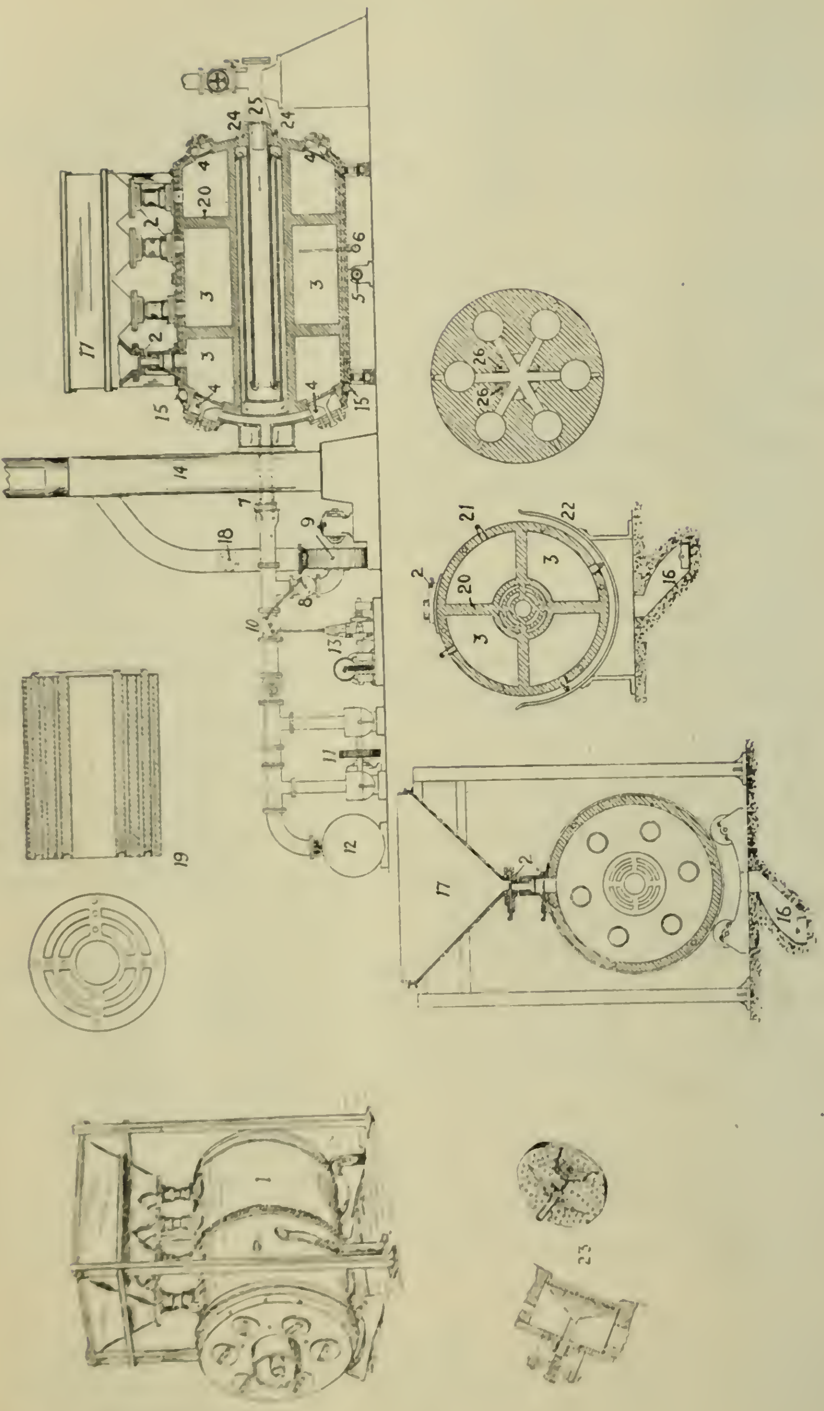

Fig. 2.
REVOLVING ROASTING FURNACE

FIG. 2.—REFERENCES.

1. Furnace.
2. Charing gates.
3. Roasting chamber.
4. Fitter boxes.
5. Worm drive.
6. Pyrometer.
7. Stuffing box.
8. Exhaust valve.
9. Exhaust fan.

10. Pressure valve. 11. Blower. 12. Air receiver.
13. Variable cam gear. 14. Flue.
15. Non-return valves for air pressure to advance to fitters and check exhaust being drawn.
16. Tunnel and drag conveyer. 17. Charge bin. 18. Bye-pass for SO_2 gas.
19. Section of re-inforced moulded radiating tubes—moulded in short lengths laced on 12 steel rods—full length of roasting furnace. As each section is placed in position slag-sand concrete under pressure forced in holes to fill space between steel rods and walls of holes. Inside tube lined chrome brick.
20. Supporting struts for radiating tubes. 21. Safety valves.
22. Guide ring rendering safety valves inoperative in down position.
23. Section of porous fitters. 24. Fuel gas cleaning plugs. 25. Gas burner.
26. Ports for conveying waste gas from radiating tubes to stack.

The furnace is heated by gas as shown, and the products of combustion pass forward and back along the internal tubes, thence by further pipes along the wall of the furnace (not shown in plan) finally to the stack.

This arrangement allows of a high temperature at the point of combustion without overheating the ore bed.

The air delivered to the ore charge is pre-heated by passing through the stack, thus further utilising the waste heat of the combustion gases.

In operation, the furnace is charged about half full and revolved at a speed of a quarter to half a revolution per minute.

The completion of the roast is ascertained by withdrawing samples of the charge from conveniently arranged plugs, and making a simple test of the amount of water-soluble copper.

The finished charge is released by turning down the furnace over the tunnel provided with a flight conveyer and opening the discharge gates.

Dissolution of Copper.

The hot calcine passes to the cone mixer to which is simultaneously added sufficient sulphuric acid solution to form a 1 to 1 pulp for the dissolving tanks. For an ore containing 5% copper, the stock solution made up from by-passed electrolyte will contain about 3.5% free H_2SO_4 (100%) and about 1% Cu.

Fig. 3 shows the dissolving tank, the action of which is fully explained in the reference.

Air, preheated by waste heat from furnaces or gas coolers, is used in the air lifts. Copper sulphate and oxide being much more soluble in hot solutions than in cold, the utilization of

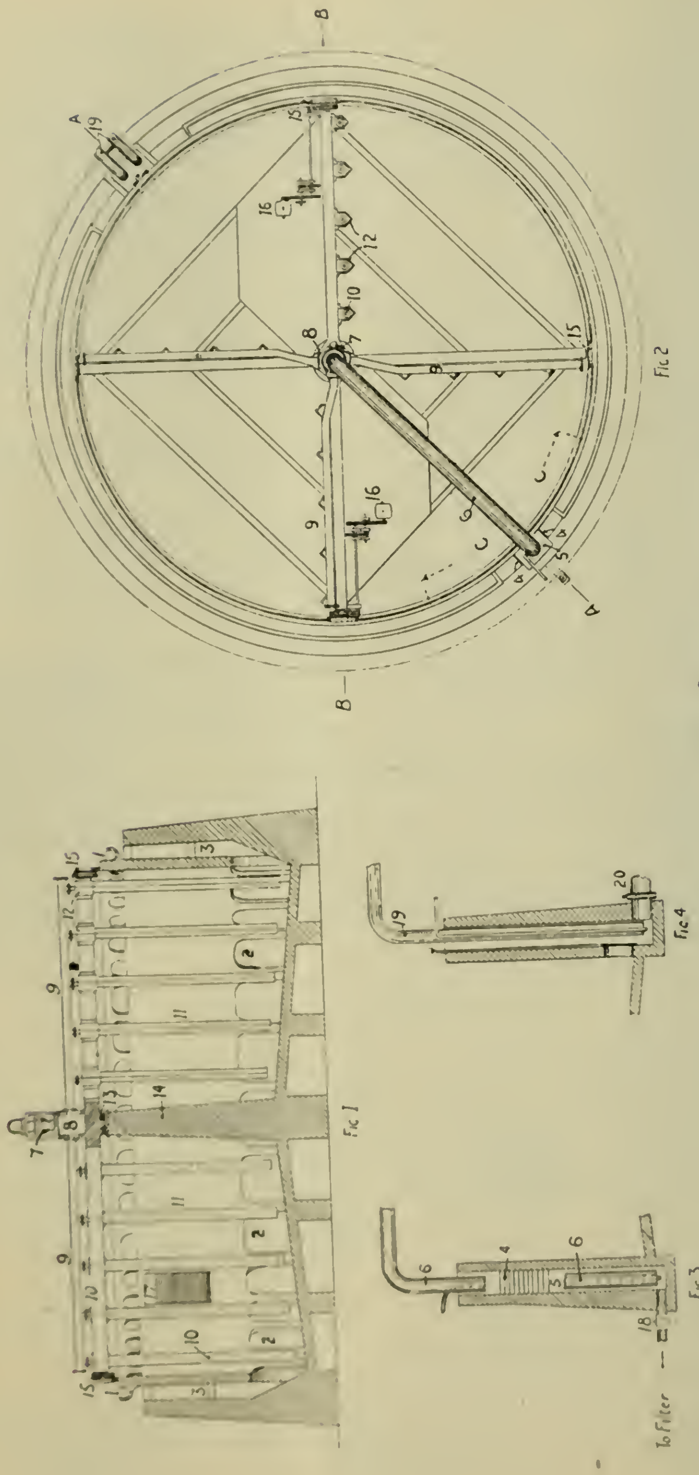

Fig. 3.

DISSOLVING AND WASHING TANKS.

FIG. 3.—REFERENCES.

Tank is charged through launder (1) arranged to distribute pulp evenly round tank. Light slimy liquors or wash waters flow under arches (2) through sand into annular compartment (3) and over adjustable sills (4) into circulating box compartment (5), and are forced up by air lift (6) through acid-proof stuffing box (7) and four-way piece (8), thence along pipes (9) to vertical pipes (10) in wooden vertical agitating arms (11), and from thence repeat cycle. Agitating arms (11) are held in cast-steel sockets (12) fastened to revolving girder frame, supported in centre on ball-bearing (13) mounted on central pillar (14). Outer periphery of revolving frame supported on wheels (15) running on circular rail round top of tank. Two wheels are geared to electric motors (16). After driving motors have been stopped, mother liquor or various slimy wash solutions flow to box compartment (5) for slimes from annular compartments (3) to be sent back to dissolving tank. Air is then shut off and liquor in tank allowed to settle, which settled liquor is now drawn off over two central adjustable sills (17) into annular compartments (3) to flow into box compartments (5) thence through cock (18) to fitter to clarify liquor. In discharging air lifts (19) are in duplicate. Pulp from air lifts goes to cone settler to denude same of coarse sand. Overflow from settler to Dorr thickener (full of water). Overflow from thickener gravitates back to dissolving tank to provide water to complete emptying of tank. The last of water in tank is discharged through sluice valve (20).

1. Half-section on line BB Fig. 2. 2. Plan view.
3. Section of circulating box compartment AA Fig. 2.
4. Section of discharge box compartment AA Fig. 2.

NOTE.—Arches (2) in inner wall stop as indicated by dotted line C. Air lifts (19) by mechanical means are raised or lowered. Current to driving motors transmitted from slip rings on centre of revolving frame.

heat in this way causes a great reduction in the time of contact necessary. All wash solutions go to separate tanks, the second wash solution becoming the first wash for the following charge and so on, with the exception of the solution required for the producer gas plant. Clean water is used for the final wash and, owing to the use of milk of lime precipitating the Cu from solution, a most efficient washing of the residues may be conducted, which in other methods would be impossible on account of the accumulation of a large tonnage of solution too low in copper to be utilized profitably.

TREATMENT OF "MOTHER LIQUOR" FOR ELECTROLYTE.

The quantity of mother liquor taken for separate treatment is calculated so that the amount of Cu contained will provide by electrolysis only sufficient free H_2SO_4 for the following purposes :—

(*a*). To dissolve the acid-soluble Cu in the ore charge.

(*b*). To react with all the acid-consuming minerals such as the carbonates of lime and magnesia which remain unaltered after a sulphatising roast.

(*c*). To acidulate the following mother liquor after neutralizing the purifying, before sending it to the electrolytic tanks.

(*d*). To dissolve the small percentage of Cu and Fe remaining in the $CaSO_4$ residue from the ammonia treatment.

The liquor, as calculated for the above requirements, is run to a special cone-bottomed vat and subjected to thorough oxidation by compressed air. Very finely divided (slimed) carbonate of lime is gradually added, only sufficient in total quantity to neutralize the free H_2SO_4 and precipitate the greater proportion of the Fe or other impurities.

The precipitate is filtered off and washed in an acid filter press, the filtrate being returned to the same vat and the washings sent to the main wash solution storage vats. The residue is treated later and marketed as a fertiliser.

Agitation is recommenced in the same vat, the temperature maintained at C., and according to the Fe remaining in solution, a calculated amount of pure CuO from the ammonia process (see pages 2 and 11) is added precipitating the Fe after the well-known reaction of Hofman.

The residue is filtered off and washed as before, but in this case it is returned to the furnace bins for roasting with the next ore charge, the Fe of the residue remaining insoluble and the Cu being recovered in the dissolving tank.

The purified solution of Cu SO_4 is now acidulated by means of by-passed electrolyte to the extent of 1% free H_2SO_4 and is sent to the electrolytic tank house.

Electrolysis is conducted with a current of 12 amp. per sq. ft. of cathode surface, the anodes being of graphite with arrangements for introducing SO_2 gas under pressure into the electrolyte for depolarization.

In the presence of SO_2 the electrolysis of Cu SO_4 solution results in the production of 2.3 lb. of free H_2SO_4 per lb. of Cu deposited. Using this factor (2.3), the amount of free acid to be produced is calculated in advance, all electrolyte being by-passed from the tank house with a Cu content of 2%.

On account of the Fe in the electrolyte being maintained below .2% (20 gm. per litre), it is possible to use graphite anodes yielding about 3 lb. of Cu per kw. hour with a current density of 12 amp. per sq. ft. Current efficiency is thus kept high, a most important consideration where power is expensive.

TREATMENT OF FIRST WASH SOLUTIONS.

The first wash solutions, together with the remaining portion of the mother liquor, go to a similar cone vat where they are given the same treatment with air and carbonate of lime for neutralization and partial precipitation of the Fe or impurities.

After the residue is filtered out and washed as before, the warm solution is agitated with gradual additions of milk of lime to produce as near as possible a "selective" action—that is, to precipitate most of the remaining Fe with very little Cu.

The precipitate from this treatment is filtered off, the filtrate returned to the vat and the residue sent to the furnace bins with the next ore charge.

Further milk of lime is added until all the Cu is precipitated as hydrate, which readily settles and filters in a warm solution.

On filtering, the clear solution is utilized to make up the stock solution for the following roasted ore charge by diluting the calculated quantity of acid electrolyte by-passed from the tank house.

AMMONIA TREATMENT.

The filtered residue, a concentrate of all the Cu of the above solutions in the form of hydrate together with $CaSO_4$ and a little Fe is immediately transferred to a sealed agitation vat and agitated with a solution of ammonia. The ammonia solution, of a strength slightly in excess of two parts of NH_3 (100%) to one part of Cu by weight, rapidly dissolves the Cu hydrate, and on completion of the dissolution, the pulp is forced through a filter press, the filtrate passing to a steam jacketed still. The first washings of weaker ammonia solution are also passed to the still, and subsequent ores are stored for use on the next charge.

All these operations are conducted in an ammonia-tight system, the storage vats for the weaker washings being arranged so as to be hermetically sealed.

The treatment in the still consists simply in forcing steam into the copper-ammonia solution and condensing the aqua ammonia driven off, the still being heated by steam in the jacket. The distillate is stored in steel tanks for the following charge. When complete elimination of the ammonia is effected, the steam is shut off, the precipitate allowed to settle and the clear solution decanted through a filter to the coolers at the producer gas plant, where the $CaSO_4$ in solution is concentrated, On the solution becoming saturated the $CaSO_4$ drops out, is recovered and converted to pure plaster of Paris. Any ammonium sulphate in solution is similarly recovered.

REDUCTION OF COPPER OXIDE.

The settled precipitate of CuO is washed by decantation and the amount required for the purification of the mother liquor for electrolyte is withdrawn to storage. The remainder of the CuO is conveyed to a small revolving furnace similar to the roasting furnace, where it is heated in an atmosphere of water gas. The reduced material is conveyed to a melting furnace where the metal is fused, poled and cast into ingots as best selected copper. This method of reduction obviates the production of a quantity of high grade Cu slag.

TREATMENT OF $CaSO_4$ RESIDUE.

The washed residue from the ammonia treatment is discharged to a mixer and sufficient by-passed electrolyte is added to dissolve the contained Fe and Cu hydrates and convert the little ammonia still remaining into sulphate. The pulp is filtered and the residue of $CaSO_4$ is washed and treated with previous $CaSO_4$ residues for fertiliser. The filtrate and washes are treated "selectively" with milk of lime to eliminate Fe, the precipitate resulting is returned to the furnace with the next ore charge, and a portion of the solution is now passed through the ammonia absorbers of the producer gas plant. The NH_3 of the water gas combines with the $CuSO_4$ in solution producing the characteristic azure-blue colour. On transferring this blue solution back to the remaining portion of treated solution, the Cu in both portions is immediately thrown down as hydrate, which is filtered off, dried and conveyed to the reducing furnace to be converted to metal by water gas.

The filtrate is now concentrated to recover ammonium sulphate, a portion of which product is heated with lime to obtain ammonia. Purified weak wash solutions from the dissolving tank are given a similar treatment to the above when required to absorb the balance of NH_3 produced from the coal. Any excess of ammonium sulphate above that required to make up the waste of ammonia in the process is disposed of as fertiliser with the $CaSO_4$.

TREATMENT OF TAILING.

In most cases the precious metals in the ore are combined with the Cu minerals, and after the extraction of the Cu a separation of the slime concentrates the gold and silver values in the slime. On agitating this slime with cyanide the precious metals are extracted together with some Cu, of which there remains about .3% in the tailing.

CONCLUSION.

To start up operations a special charge is roasted and the water soluble Cu extracted. After purifying the liquor obtained, a small quantity of purchased acid is required for the necessary acidulation and the subsequent electrolysis will provide free acid for the future operation of the plant.

The ammonia required will have to be procured until the producer gas plant is in operation, after which, the losses to be made up will be no more than in good freezing plant practice.

Water consumption will be the amount of moisture discharged with the residues, the amount evaporated, and the waste steam of the power plant not condensed, including that required in the producer plant.

Solutions after treatment with milk of lime are perfectly free of Cu.

The $CaSO_4$ formed in the hot solutions causes no trouble in pipe lines.

Throughout the process all solids filter readily.

Reagents are regenerated or converted to by-products.

There are no foul solutions, no solutions are discarded, and no Cu is tied up in unfinished products.

The process is a chemical one, and each step may be calculated chemically. If excess $CaCO_3$ be used to purify solutions, the excess will be coated with an oxide of Cu. Coarse $CaCO_3$ has little or no action in purifying.

Milk of lime should be as free as possible of $CaCO_3$.

Solutions of $CuSO_4$ should be warm, not boiling, when under treatment. Milk of lime should be gradually added, otherwise precipitation is impeded and excess of lime precipitate is accumulated. Copper hydrate precipitate should not be kept too long before treatment. Ammonia solution for dissolving should be about 20% NH_3 and only the final wash for the residue from the ammonia treatment should be clean water. Previous washes should all be weak ammonia solutions, otherwise Cu is precipitated out of solution.

As power is expensive at most mines it is much cheaper to produce electrolytic Cu from a portion only of the liquors as required to produce the necessary H_2SO_4, and to convert the excess Cu in solution to oxide, thence to metal, than to electrolyse the whole of the solutions from the ore charge.

PROCEEDINGS AUS. I.M.M. (INC.)] [N. S., No. 42, 1921.

THE ARTIFICIAL VENTILATION OF THE BROKEN HILL PROPRIETARY MINE, N.S.W.

BY R. T. SLEE.

(*Read before the Broken Hill Branch, July* 1920.)

UNLIKE coal mines, in which some form of artificial ventilation is rendered necessary by gases given off by the material mined and is also enforced by the mining laws of all countries, metalliferous mines have almost entirely relied on natural ventilation, viz., that due to the difference in temperature between the outside atmosphere and the mine air. In small mines natural ventilation has proved sufficient, but as mining proceeds at a greater depth, and where large ore bodies are being attacked the writer is of opinion that some means of artificial ventilation will be rendered necessary if only from an economic standpoint.

The Broken Hill Proprietary Mine was one of the first metal mines to introduce a scheme of artificial ventilation on a large scale.

In order to render the working conditions of the semi-friable stopes of Block 12 and the lower levels of Block 11 more comfortable for the men at work in these places, in 1903 it was decided to install a fan to thoroughly ventilate these stopes. The fan chosen was a Capell double-inlet fan belt-driven from a steam engine: this engine was later on replaced by an electric motor. The fan was put in commission at the latter end of 1904; its principal dimensions are as follows:—Length 6 ft. 6 in., diam. 7 ft., diam. of inlet 4 ft. 7½ in. The fan is reversible, though this is a rather misleading term, as the direction in which the fan blades revolve is not reversed,

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but the entry and discharge of the air-current. The sketches (figs. 1 and 2) show the arrangements of the various doors, etc., thus con-

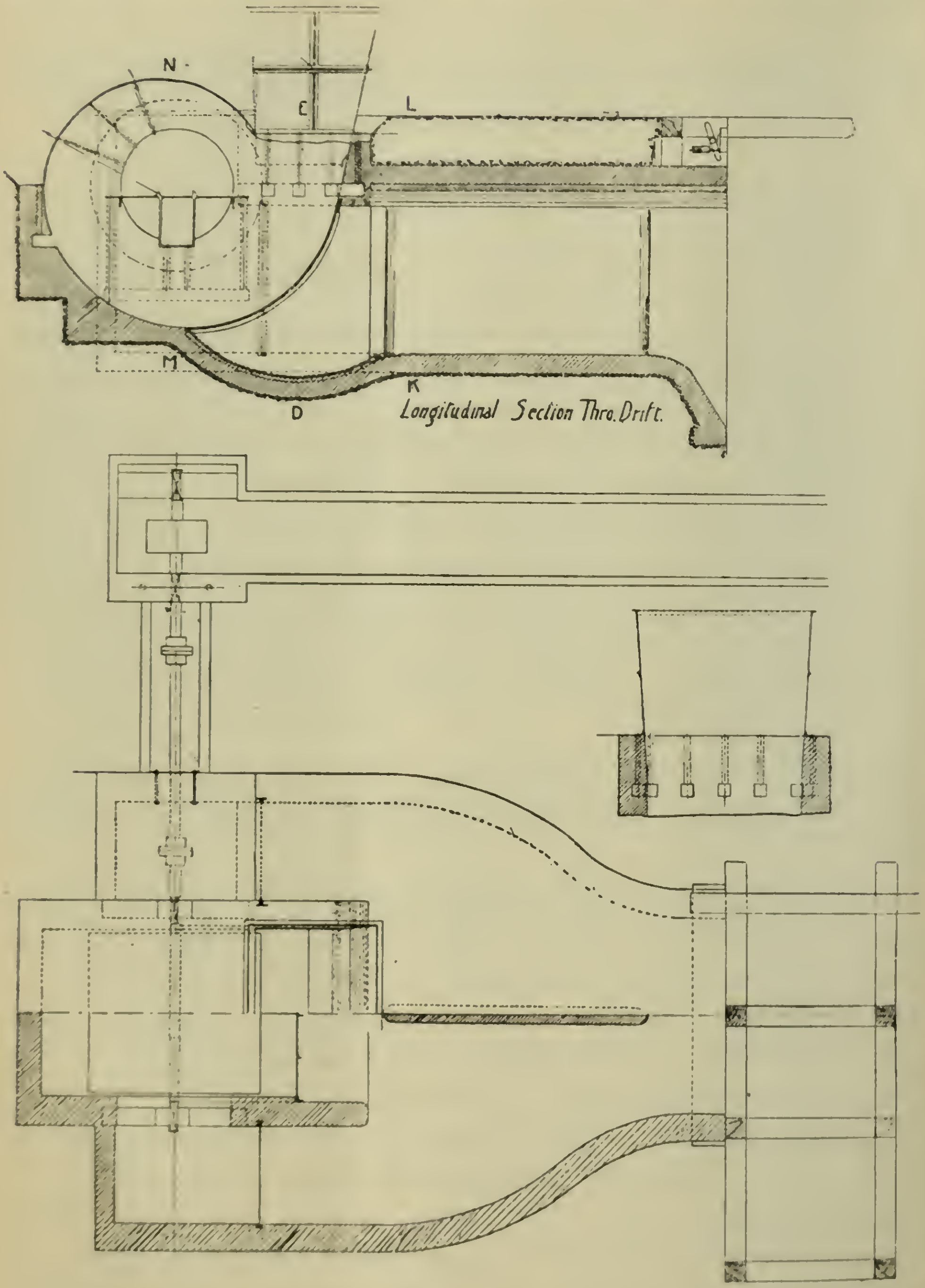


Fig. 1

Ventilating Fan for Dickenson's Shaft.

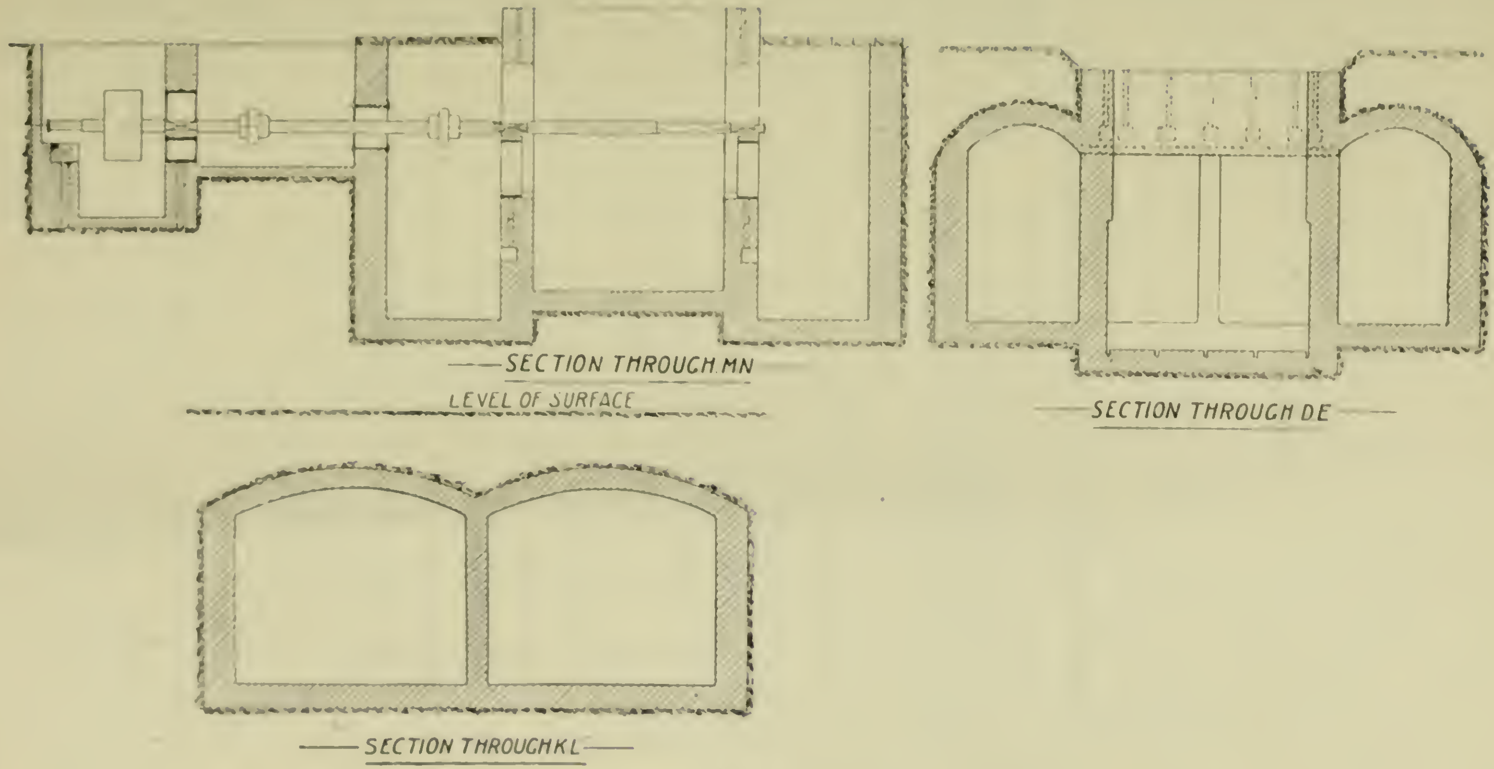


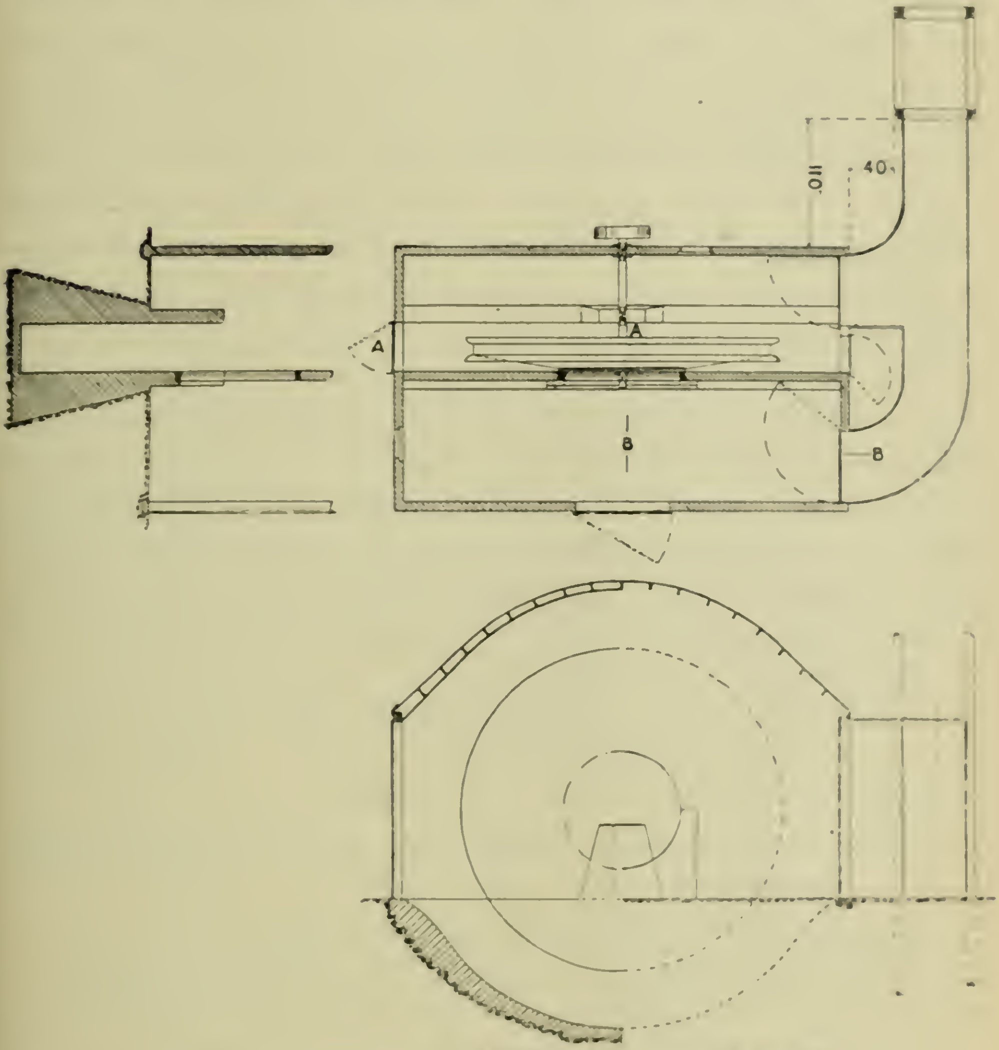
Fig. 2.

Sections Showing Arrangement of Ventilating Fan for Dickenson's Shaft.

trolling the air-currents. When running under normal conditions the fan is exhausting Delprat's and Stewart's shafts and several old shafts to the north act as downcasts, and Dickenson's shaft, at which the fan is situated, being the upcast. The intake air passes down the shafts indicated, along the lowest level and up through the workings to the 500-ft. level, thence to Dickenson's shaft. At first the lowest level working was made the intake, but mining operations rendering necessary a better circulation than this afforded, the lower levels, that is all levels below the 650 ft., were made intakes and, to ensure this, doors were erected on all levels above the 800-ft. level, which thus prevented the air short-circuiting to Dickenson's shaft. When running at full speed, 360 r.p.m., the volume of air in circulation was 75,000 cub. ft. per min.

Owing to the fire in 1906 the ventilation was much interfered with by the erection of stoppings in the various levels, and also owing to the fact that the fan was run at a reduced speed in order to decrease the draw on the fire. To remove the fumes which were emitted from the southern side of the fire-area, and to permit of the starting of the workings adjacent thereto, a fan was erected at Weatherley's shaft, situated on Block 11 and near to the Block 10 boundary. The well known Waddle type of fan was installed here, which being an open-running fan necessitated rather different arrangements for reversing the air-current. This, so far as the writer is aware, has not been done previously with a fan of this type. The sketch (fig. 3) showing the arrangements of the surface may be interesting. On referring to the ventilation diagram it will be noticed that the intake with both fans working remains unaltered, but at about 1000 ft. from Delprat's shaft the air-currents split when ascending the workings, a portion making its way to Dickenson's and a portion to Weatherley's shafts. As the ventilation is ascensional fullest advantage is taken of the natural law of hot air to ascend and colder air to take its place. The air-current also ventilates lower exploratory workings by means of winzes as shown at the blind shaft, Block 11.

When measuring the quantity of air in circulation, the writer proceeds as follows:—The No. of r.p.m. of fan taken, the ammeter and voltmeter read, and the driver instructed to maintain a constant amperage. The writer and assistant then proceed below and measure the quantity of air passing through each crosscut of the upcast shafts. Places for observation are chosen where the crosscut is of fair uniform cross section. The area of cross section is measured and spot selected



SECTION A A SECTION B B

FIG. 3.

VENTILATING FAN AT WEATHERLEY'S SHAFT.

marked in chalk on the sides and back of crosscut—to illuminate these marks the writer uses a portable electric lamp. The anemometer is then fixed to a tamping stick and the observer and assistant station themselves on the upcast side of the mark. The observer holds the instrument so that the vanes are square to the current being measured and moves it slowly over the whole of the section of the crosscut where practicable, only moving his arm, having stationed himself so that his body offers the minimum amount of resistance to the air-current. On starting the anemometer the observer gives a signal and the assistant notes the time in minutes and seconds. After traversing the section and stopping the anemometer the observer gives another signal and the difference in the two times gives the length of time of observation. The difference in the reading of the anemometer before and after divided by this time gives the velocity in feet per min.: to this is added the instrument correction and the result is the correct velocity at that particular cross section: this is repeated two or three times and the mean result taken.

The average amounts of air in circulation are as follows:—

Prior to the fire in 1906:—

Dickenson's fan circulated 75,000 cub. ft. per minute, running 360 r.p.m.

After the fire:—

This fan circulated 58,000 cub. ft. per minute, running 330 r.p.m.

Weatherley's fan—All shaft timbers in place:—

Circulating 39,500 cub. ft. per min., running 48 r.p.m.
,, 51,600 ,, ,, ,, ,, 64 ,,

Weatherley's fan—All shaft timbers removed:—

Circulating 50,000 cub. ft. per min., running 49 r.p.m.

Dickenson's fan in 1908:—

Circulating 47,500 cub. ft. per min., running 240 r.p.m.

The total quantity of air in circulation is thus 97,500 cub. ft. per min., or average of 200 cub. ft. per man and horse employed in the mine.

Both fans have been run forcing the air through the mine, and there was no appreciable difference in the quantity of air in circulation.

In any criticism of the foregoing results it should be borne in mind that the ventilation scheme of a colliery is of paramount importance, and the shafts and workings laid out with that end in view, whereas in the Proprietary Mine the ventilation had to suit workings already in existence, as witness the marked increase in the air circulating at Weatherley's shaft when the shaft timbers were removed.

For the purpose of showing that the fans have a cooling effect, the following calculations worked out on lines laid down by Dr. J. S. Haldane may prove interesting. There is no appreciable difference in the O contents of air outside and inside, at any rate in the first decimal place. The temperature of the outside air was 63° F by dry bulb, and 51° F by wet bulb. The temperature of the upcast air 70° by both thermometers. From Glaisher's tables we find the difference in weight of aqueous vapour to be 5.2 gr. per cub. ft. for the temperature given, and the increase in temperature 7° F. The moisture would carry off latent heat equivalent to that produced by the disappearance of .156% O, and the rise in temperature between intake and upcast air-heat equal to a loss of .026% O. Thus the heat carried off was equal to that produced by a total loss of O of .156 plus .026, equal to .18% O, or sufficient to have heated the air by 50.5° F, whereas the actual increase was only 7° F.

Another advantage of a regular system of ventilation is the fact that the fumes from blasting are rapidly carried away, and in a mine where an average of 600 lb. of explosive are used daily this is an important consideration.

Apart from the regular system of ventilation auxiliary ventilation for drives and winzes is also carried out. Prior to 1904 the stopes in Block 13 mine between the 400-ft. and 500-ft. levels were ventilated by a small exhaust fan placed over the central mullock pass of the stope on the 400-ft. level.

The customary means adopted for ventilating drives and rises consisted of galvanized-iron pipes conveying air to the face, the current being produced by either air or water jets. The foregoing method is also employed in stopes in which the ventilating current is sluggish ; this applies more to square-set stopes than to open stopes. The pipes used are generally 14 in. diam., though 20 in. diam. and oval pipes have been used. All pipes are flanged and bolted in position, the joint is made air-tight with gasket. Joints made as indicated are more reliable than ordinary spigot and faucet joints often packed with pieces of paper. In most cases the pipes are laid along the bottom of the drive ; in that position they are more easily protected from flying stones from blasting and can be kept closer to the face. When pipes are fixed in the back of the drive they are kept about 100 ft. from the face—to bring the air to the face a canvas pipe is used. The canvas pipe is strung on a wire reaching from the galvanized-iron pipe to the face ; one end of the canvas pipe is fitted on the iron pipe, and using it concertina fashion it adjusts itself to varying distances of the face from the iron pipe. The canvas pipe is always removed prior to blasting, and is used in 30 ft. and 60-ft. lengths. To allay the dust of explosion and cool the face use is made of a water gun ; this consists of a section of 8-in. pipe let into the air-main supplying compressed air to rock drills at the face and fitted with the necessary connection as shown (fig. 4) for filling with water.

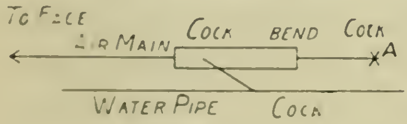


Fig. 4.

Its operation is as follows :—

The cock, A, on air-main is closed just prior to firing, the hoses at the face disconnected and the bend of air pipe pointed at the face, the connection on water pipe opened and the large pipe filled with water ; when filled the water is shut off. On the miners spitting the fuses and withdrawing from the face as soon as the holes explode, the cock, A, is opened and the compressed air forces the water in front of it, issuing as a fine spray, and lays the dust.

The following figures show the quantity of air thrown, the head for water jets and the pressure for air:—

Air Jets:—300 ft. head, 200 ft. long, oval pipe, 950 cub. ft. Water jet, 1280 cub. ft. Water and air jets combined.

Drives:—Water jet 400 ft. head, 220 ft. long, several bends, 708 cub. ft. per min. Water jet 400 ft. head, 120 ft. long, 2 right-angle bends, 633 cub. ft. per min.

Rise:—Water jet 200 ft. head, 64 ft. long, 30 ft. of 14 in. pipe, then 34 ft. of 10 in. pipe, 1 right-angle bend (the bend was not too clean when the air was measured), 523 cub. ft. per min.

Air jet for inclined rise 80 ft. long, 10 in. pipe, spigot and faucet joints, air-pressure 75 lb. per sq. inch—350 cub. ft. per min.

Air jet for drive and winze 100 ft. long, 10 in. pipe, two bends, 75 lb. per sq. inch—391 cub. ft. per min.

Where there is sufficient head and the water can be easily disposed of a water jet is preferable to an air jet.

In other places small fans have been used. A Sturtevant blower had a capacity of 4000 cub. ft. per min. and an electric motor-driven fan 8000 cub. ft. per min. When installing pipes, conveying air from fans, the pipe should have such a diameter that the velocity of the air will not exceed 1000 ft. per min., otherwise the fan's capacity is reduced.

Whilst the main ventilation is exhausting, in re-opening the fire-areas for productive work local pressure fans were employed as more suited to the conditions.

The area above the 300-ft. level was not connected with the main ventilating system, therefore a fan was installed at the top of the winze and air forced down through a pipe to an air-tight chamber, from which smaller pipes were led to the working faces, thus ensuing good air at the point of attack.

The 1906 fire-area, before referred to, when being re-opened was similarly ventilated by a pressure fan. This area could have been ventilated by the return air in the main current, but in the interests of health the management decided to force fresh air from the surface through these workings and thence into the return air-current of Weatherley's fan.

Where small fans are used for local ventilation, it is a wise precaution to arrange suitable doors and connections on the intake and delivery sides in order that the fan may either be used exhausting or forcing.

THE USE OF EXPLOSIVES IN STEEL WORKS.

By R. T. SLEE.

(*Read before the Broken Hill Branch, July,* 1920.)

In presenting the following short paper the writer hopes to illustrate some uses of explosives in industrial work under conditions different to those prevailing on mining fields. This paper is based on experience gained at the Newcastle steel works of the Broken Hill Proprietary Company Limited.

The management had decided that as soon as No. 2 blast furnace—which is of an improved design—was ready to be put into commission, No. 1 blast furnace was to be dismantled and reconstructed to a similar design to No. 2 furnace. This reconstruction entailed the removal of the brick lining of the furnace shaft, and also the removal and disposal of the "salamander" and hearth-lining. For the information of members who may possibly be unacquainted with the term "salamander," it might be explained that this term is used by iron metallurgists to denote the mass of iron and slag formed at the bottom of the furnace whilst in commission.

The method of disposal depends upon the size and nature of the salamander, and in the case under review it was decided to bury it below the hearth of the furnace to be reconstructed. A passage-way was made in the concrete walls of the cast house, and the sand-filling of the cast house removed sufficiently to allow of the concrete foundations of the furnace being reached. This passage-way was extended until the hearth was encountered. The next operation was the removal of the hearth-lining below the salamander. The removal of the concrete was not difficult;

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holes were drilled by the use of "jackhamers," charged with gelignite in the usual way, and fired by ordinary fuse and detonators.

At first some difficulty was experienced in inducing the operators to take the necessary precautions to prevent danger from flying fragments, but this difficulty (which was due to inexperience on the part of the men) was soon overcome.

On reaching the hearth it was found to be still very warm—in fact, so warm that it was necessary to work the men in spells whilst in its vicinity.

In order to salvage as many as possible of the two bottom rows of hearth blocks (which appeared to be in good condition), the next operation was to remove the concrete foundation below them; the excavation thus made would also serve as a receptacle for the salamander providing the quantity deposited was not too large.

The same drills were used for boring purposes, but the size of the bits was increased; every hole as drilled had a water hose placed in it in order to cool its walls and to prevent a premature explosion when charging. When ready to fire, each hose was removed and the charge pushed home; the charge was wrapped in a clay envelope as an additional precaution. The use of large-size bits was necessary in order that the clay envelope containing the charge could be inserted with ease.

Many hearth blocks were salvaged by the use of crowbars and an occasional "pop."

As the excavation progressed under the salamander, props were used to prevent it from falling; all the brickwork up to the iron was removed, and also for the space of about 9 in. outside its circumference.

Whilst the excavation was proceeding, the work of dropping the salamander was also put in hand, and this work called for the drilling of holes around the circumference; in all, 15 holes, each about 4 ft. deep, were drilled; these holes were chambered to receive larger charges of explosive. Before charging these holes, a protecting fence of railway sleepers enclosing the space between the top of the hearth jackets and the tuyere jackets, was lashed into position. Each hole was then charged with 18 plugs of gelignite, and electric detonators were utilised. For the first two attempts the detonators were connected in series and a rack-bar exploder used. On the first trial one hole only exploded; on the second, only three holes exploded.

In view of these failures, the contractor consented to try another method. The sand tamping was blown out by the use of compressed air, and the detonators removed; fresh detonators and primers were inserted, and the detonators were then connected to the leading wires in parallel. Instead of the exploder being used, current was obtained from the power circuit. By using this method all the holes exploded, but owing to the two previous miss-fires the salamander dropped about 2 ft. only, and then hung up. It was again propped up, and the debris removed. When this work was completed it was found that the salamander was free all round its circumference. A cement bed was prepared for its reception—the supporting props fired, and the mass dropped; all timber was then removed and the salamander concreted in position, forming a foundation for the new hearth-lining.

Another case in which explosives were used was in removing a parapet in order to extend the cast house, and for this purpose it was necessary to remove about 30 ft. in length of concrete, 2 ft. high and 2 ft. thick.

Instead of using hammers and gads, it was decided to blow the parapet off, taking care of course that the wall was not injured by the charges. This work was carried out in the following manner:—The grade line was marked on the parapet, and holes drilled about 3 in. apart; the first hole pierced the parapet completely, the next was about 16 in. deep, and the drilling performed in that manner till the whole length of 30 ft. was covered. Light charges of half-plugs of gelignite were placed in solid holes about 2 ft. apart, and fired. The line of holes was the line of fracture, and no damage was done to the wall beneath.

On another occasion the metallurgical staff desired to examine the interior of three forging ingots, which were the first ingots cast in the steel foundry using a cast-iron mould. It was desired to split the ingots longitudinally, and it was thought that explosives might be used to bring about this result.

The first ingot was drilled with 11 1¼-in. holes, placed 12 in. apart, and 18 in. deep. A trial showed that charges fired for the purpose of chambering had very little effect, the chambered holes only taking from one to two plugs more than the untreated holes in order to give the same depth of charge. Ten holes were charged, the remaining hole being rejected on account of it having ended in slag. The ten holes took 65 plugs; the electric detonators were inserted, and each hole tamped to the collar with clay; the detonators were connected to the firing-wires in parallel. The whole ingot was then covered with sand-bags in order to prevent danger from flying fragments. The firing-wires were connected to a two-pole switch connected with the power circuit; by closing the switch the holes were all fired simultaneously. The result was a thin crack the whole length of the ingot, but apparently only about 6 in. deep as a close examination of the butt-end did not reveal a greater depth.

The holes were again charged, using 85 plugs, and fired as before. This time the ingot was split completely in halves; the two pieces were thrown about 50 ft. from the original site as a result of the explosion.

The second ingot was drilled in a similar manner, excepting that about six holes were drilled from the opposite side and arranged to pass between the holes on the other side. The same procedure was followed as in the first case, 85 plugs being used; a crack similar to the one in the first ingot was the result. Thirteen holes were then recharged, using 65 plugs, and refired. The ingot was completely split, and the top half thrown for a distance of about 6 ft.

In the third ingot the holes were placed 9 in. apart—27 holes in all, drilled from both sides, and charged with 120 plugs; they were then fired as before. The first explosion completely split the ingot, and also broke the two halves circumferentially; one piece was thrown 6 ft. away, and the other about 18 ft. away.

A feature of the splitting of the third ingot was the fact that, as a result of the explosion, a cast the length and shape of the ingot was made in the ground, about 4 ft. deep at one end and tapering to 6 in. at the other end. The depression made by the splitting of the first two ingots was hardly noticeable.

Explosives were also successfully used at Newcastle for loosening the accretions formed on the bottoms of the open-hearth steel furnaces after a campaign.

In any criticism of the foregoing, it should be borne in mind that the explosives were used under conditions very dissimilar to those obtaining in either mining or quarrying operations, and the writer trusts that the results given will be of interest to his fellow-members.

MECHANICAL METHODS OF ALLAYING DUST.

BY P. H. WARREN.

(Read before the Broken Hill Branch, 31*st May,* 1921.)

ATTENTION has recently been directed to the subject of dust-production and methods of allaying same in the Broken Hill mines, so that the time would seem opportune for the local branch of the Institute to discuss certain features of an important phase of the health question in connection with underground work.

Tests conducted in the Broken Hill South mine and at other mines at Broken Hill have shown that the ordinary operations of mining, such as boring, blasting, and shovelling, may be accompanied by the production of considerable dust unless water is judiciously used.

In South Africa dust particles under 5 microns size are regarded as dangerous, because they are so small as to be invisible to the naked eye, and will escape the protections set up by nature in the nose and throat, and thus may be inhaled in large quantity. A micron is 1/25000th part of an inch.

This paper contains an account of the work done on the Broken Hill South mine chiefly, though some tests were done on other local mines.

An acknowledgment is due to Mr. T. A. Read, of the Broken Hill South mine, who conducted some of the tests herein mentioned, and under whose supervision most dust counts were made.

Numerous dust samples have been taken by means of the konimeter, an instrument designed by Dr. Kotze, the Government mining engineer of the Union of South Africa, and fully described

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in the *Journal of the South African Institution of Engineers*, March, 1918, in a paper by John Innes, also in the final report of the Miners' Phthisis Prevention Committee, South Africa.

The following figures show average dust counts from many different samples, all of which were obtained under working conditions prior to May, 1919 :—

Remarks.	Total Dust per cc.	% under 5 microns.
Surface air—fine day	3	100
,, ,, —high wind	50	96
Downcast air	2	100
Upcast air	220	100
DRIVES AND CROSSCUTS—		
1. *Boring*, chiefly piston drills, *outside jets* (average of 6 samples)	297	95
2. *Filling*—average of four samples ; jet had been used to water pile down	313	96
3. *After Firing*—17 holes. Average of three samples ; water-blast turned on for 12 minutes before sample taken	147	96
RISES—		
1. *Boring*—Average of three samples, using outside jet	611	97
Average of three samples using Clifton apparatus	374	96.5
2 *After Firing*—No water used ; blown out with air for 10 minutes	1810	94
STOPES—		
1. *Filling ore into trucks and chutes*—		
Average of 5 samples	133	—
(1) The piles were wetted down with the hose	—	—
(2) No water used	352	—

Remarks.	Total Dust per cc.	% under 5 microns
STOPES—*continued*		
2. *Boring*—		
(*a*) Piston drill with outside jet ..	398	—
(*b*) Piston drill with outside jet; 5 pops fired 1 hour previously	850	—
(*c*) 22 p. Waugh popper, outside jet; average of 10 samples	636	96
(*d*) 22 p. Waugh popper, with Clifton apparatus	177	96
3. *After Firing*—		
(1) No water used; fired 30 min. previously	772	100
(2) Fired 4 holes; no water used; taken as men returned	3197	98
(3) As per No. (2), after wetting down with jet	2670	100
(4) As men returned after firing; no water	2808	98
(5) As men returned after firing; no water	1305	98
Average ..	2495	
(6) As per No. (5), after wetting down with hose	1113	98

A study of the figures supplied indicates that the use of water with boring machines, and for wetting down piles of material before shovelling, makes those operations practically dust-proof.

The dust caused by firing can be effectively dealt with by means of the water blast, as will be shown later.

During the recent cessation of work the opportunity was taken to conduct many tests on the Broken Hill South mine, and numerous dust samples produced by the various operations of underground work were taken and counted.

The Clifton apparatus, of which a description follows, was also thoroughly tested and developed by members of the underground staff for use with telescopic feed drills on rise holes and dry head hammer poppers in place of the outside jet.

The following table summarizes the results obtained, the figures given being the averages of numerous samples of each class of work:—

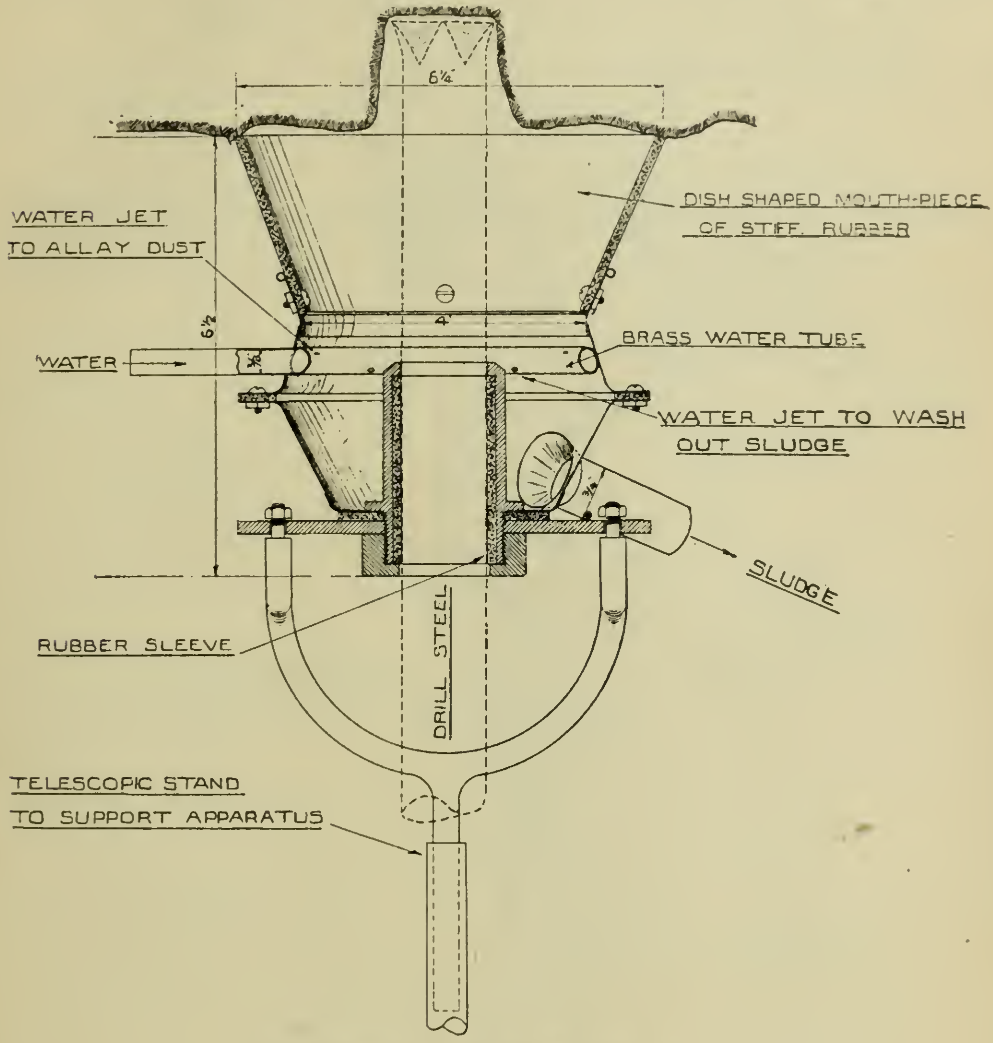
No.	Classification.	Total Dust Particles per cc.	% under 5 microns
1	Piston drills with outside jet	233	95
2	Axial water feed machines—		
	(*a*) Ingersoll Leyner	289	94.5
	(*b*) Waugh Dreadnought	146	97.4
	(*c*) Waugh Clipper	295	91.2
	(*d*) Waugh Turbro	286	96
3	Dry Head Hammer Poppers (Waugh 22 p.)—		
	(*a*) Outside jet	717	96
	(*b*) With Clifton apparatus	54	98
4	Rise holes bored with dry head hammer drills—		
	(*a*) Outside jet	963	80
	(*b*) With Clifton apparatus	45	86

THE CLIFTON DUST COLLECTOR.

The Clifton dust collector was first submitted to the Broken Hill South Ltd. in December, 1918, by Mr. D. Clifton, of South Broken Hill.

The apparatus, as originally designed for use in rises, is shown in the accompanying illustrations, Fig. 1 and Plate I. Patent Specification No. 9478, 9th December, 1918, Commonwealth of Australia, contains a detailed description of the original apparatus.

The essential features of the appliance are a dish, which, when in use, is forced up to the rock face, the drill steel working through it, and which is supported upon an independent telescopic stand. The water is supplied to the dish by means of a ½-in. hose, terminating in a pipe encircling the interior of the dish. The pipe is provided with 6 small jet holes—three on the upper surface of the pipe, placed so as to direct three small jets to the collar of the hole, and three on the lower surface to provide for washing the cuttings out of the dish into the sludge pipe.


6¼"
DISH SHAPED MOUTH-PIECE OF STIFF RUBBER
WATER JET TO ALLAY DUST
6½"
4"
WATER
BRASS WATER TUBE
WATER JET TO WASH OUT SLUDGE
⅜"
SLUDGE
RUBBER SLEEVE
DRILL STEEL
TELESCOPIC STAND TO SUPPORT APPARATUS

SECTIONAL ELEVATION

FIG. 1.
ORIGINAL CLIFTON DUST COLLECTOR FOR DUST IN RISES.

Tests with this apparatus showed that it possessed two important advantages :—

(1) It tended to confine the water, making the work cleaner and drier for the men.

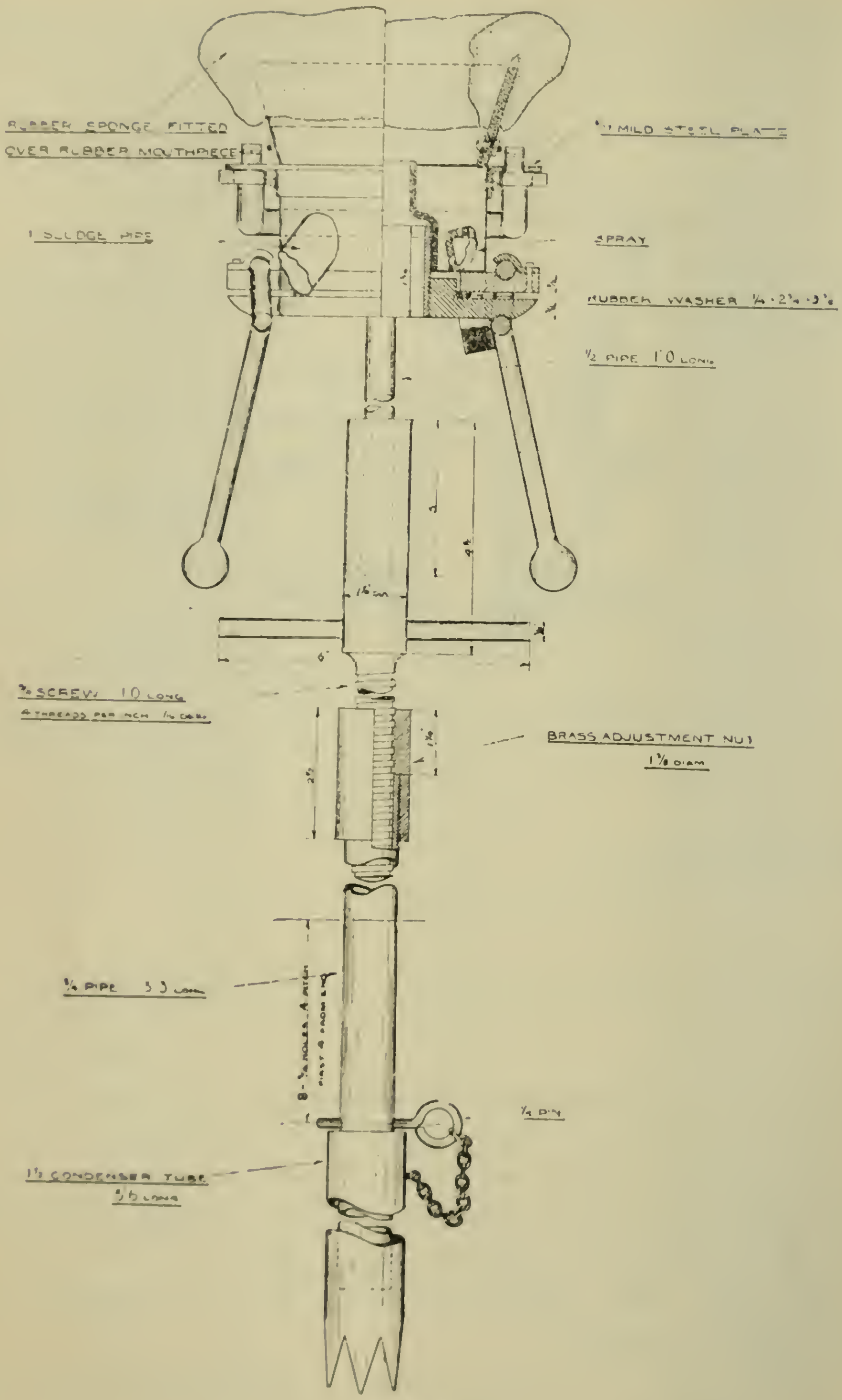
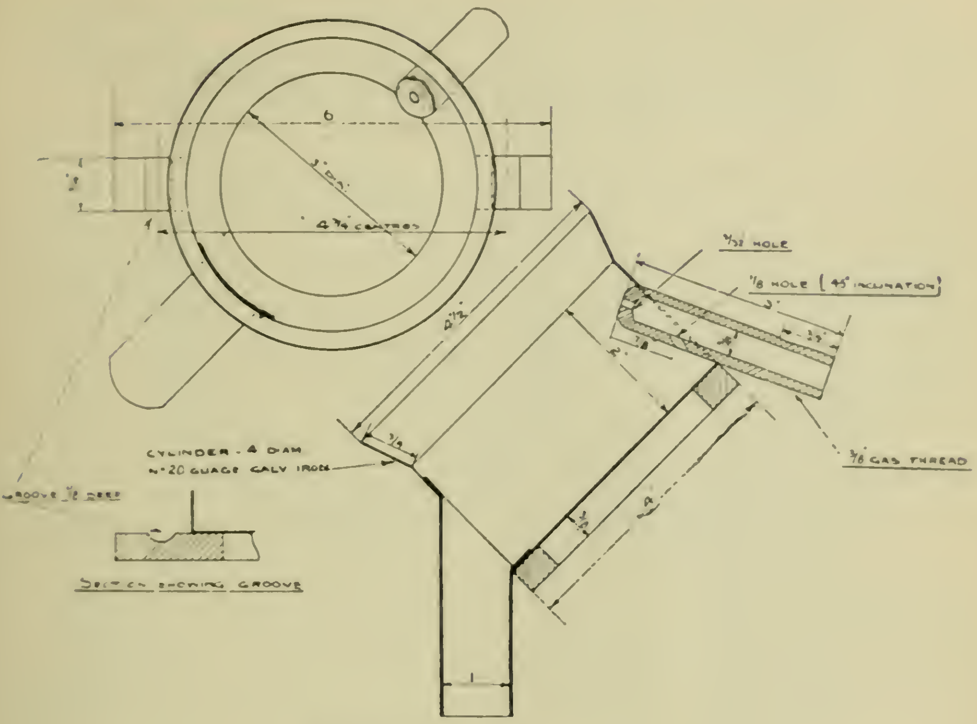
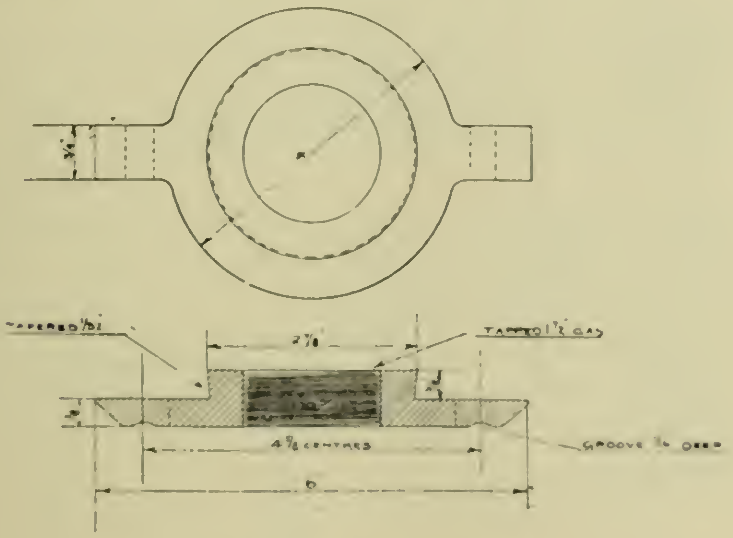


FIG. 2.
IMPROVED CLIFTON DUST COLLECTOR FOR USE IN RISES.



DETAIL

showing Arrgt of Top Plate, Sludge Pipe, Spray etc



Detail of Bottom Plate

FIG. 2a.
IMPROVED CLIFTON DUST COLLECTOR FOR USE IN RISES.

(2) Dust counts were low as compared with the outside jet average of many samples, showing 367 particles per cc., 90.2 % of which were below 5 microns in size.

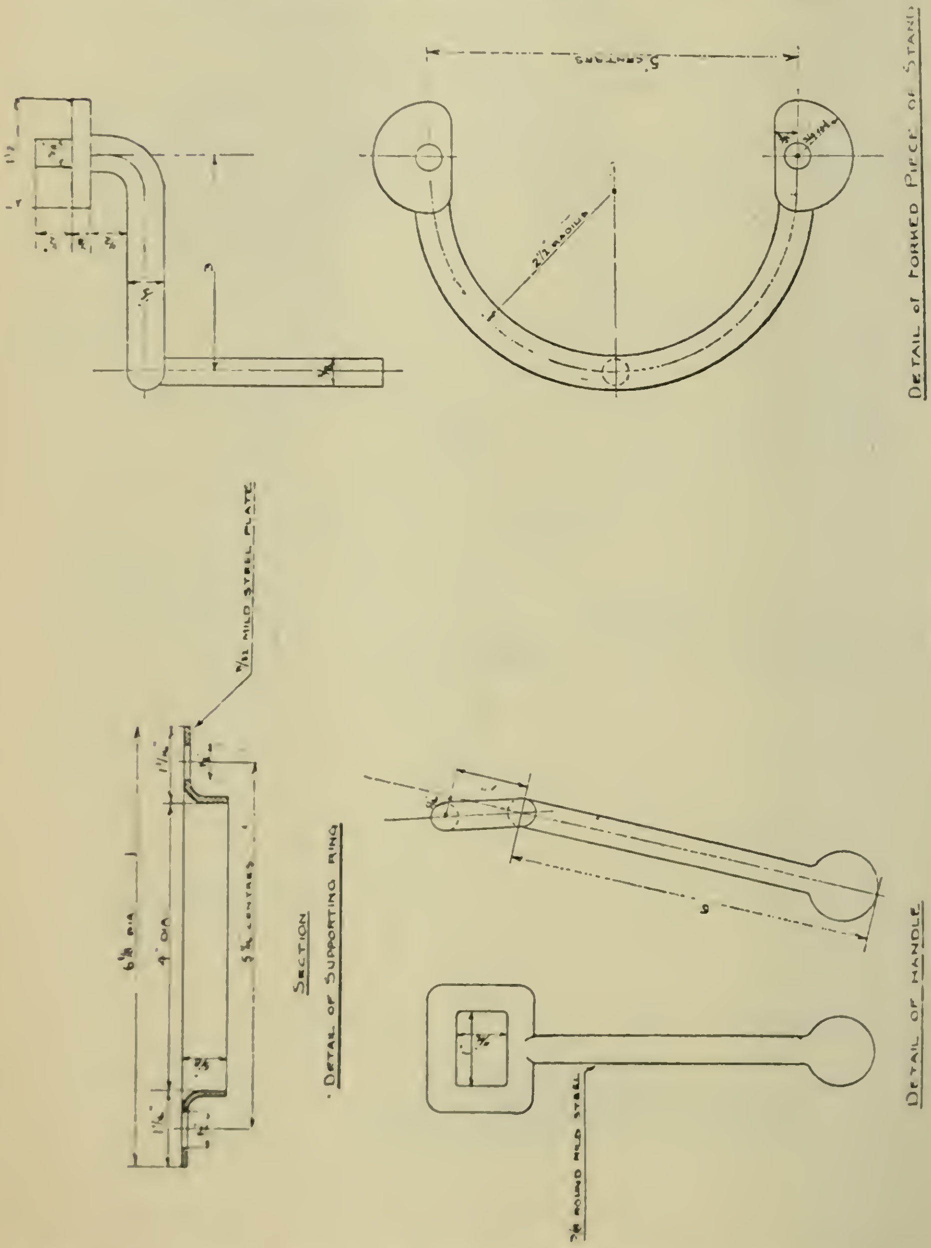


Fig. 2b.
Improved Clifton Dust Collector for use in Rises.

The apparatus has now been considerably improved by the efforts of the members of the underground staff, and, as now used, is illustrated in Figs. 2, 2a, and 2b.

The following is a list of the improvements effected :—

(1) Attachment of rubber sponges to top of dish, effecting a much better joint to the back, making the apparatus practically water and dust-proof.

(2) A movable bottom, enabling the apparatus to be left in position while steels are changed.

(3) The provision of a rigid stand, shown in Fig. 2. The quick thread of the upper portion of the bar permits of the apparatus being wedged tightly against the back; thus a good joint against the rock face is secured, and at the same time the dish is held so rigidly in place that drills may be changed without fear of a collapse, eliminating a source of inconvenience and loss of time that was a feature of the original apparatus.

Plate II shows the apparatus set up for work underground.

Averages of dust sample counts obtained by using the improved Clifton in combination with a Waugh 16-v. telescopic feed drill give a result of 45 particles per cc., 86 % of which were under 5 microns in size.

Fig. 3 shows a modified form of the apparatus designed and tested on the mine for use with poppers. The popper is extensively used in the Broken Hill mines, not only for boring holes in large rocks, but also for cutting hitches in timber work, while the heavier "jackhamer" is sometimes used for winze and shaft sinking.

As previously mentioned, local practice in the past has been to apply water in the form of an outside jet for the suppression of dust. The use of such machines, therefore, meant the employment of two men per machine in order to ensure an adequate supply of water to the hole. It was not, however, unusual to find men boring dry with poppers, despite the fact that such practice is not only a contravention of the *Mines Inspection Act* of New South Wales, but is also condemned alike by the management and the local miners' union.

The modified form of the Clifton apparatus adopted for this purpose is entirely successful, not only because the dust is almost completely suppressed, but the employment of an additional man is rendered unnecessary.

Samples of dust from Waugh 22-p. poppers using the Clifton gave an average dust count of 54 particles per cc., 98 % being under 5 microns in size.

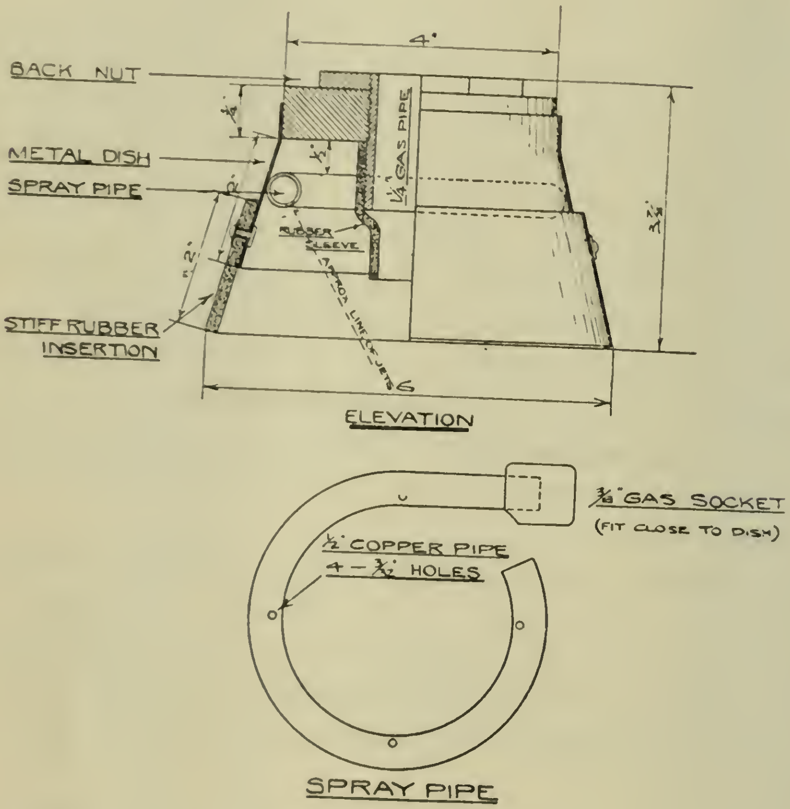


Fig. 3.
Improved Clifton Dust Collector for use with Poppers.

A study of the dust count figures makes it clear that the Clifton apparatus effects considerable improvement in dust-allaying, in rising and popping work, as compared with machines using an outside water jet.

Further, there is the important consideration that in the case of rising the work is made cleaner and drier for the men, and the mechanical application of water renders the employment of two men with the popper or "jackhamer" unnecessary.

The combination of the Clifton apparatus used with solid steel hammer drills of the Waugh 16-v. type, or used dry with wet telescopic feed drills of the hydromax type—in which case the dish acts as a return water catcher—is perfectly satisfactory. The only wearing part is the rubber sleeve through which the steel passes. The internal lining of disused air hose is utilized for this purpose. Changing steels is a simple operation, and it entails no loss of time.

The apparatus, however, is not suitable for use with piston drills, nor can it, in its present form, be used with collared steel.

The use of Clifton's appliance in the manner indicated provides a means of doing rise work which, in the matter of cleanliness, freedom from dust, and low machine repair costs, compares favourably with the work done by axial water feed drills of the Ingersoll Leyner type.

The mechanical operations of underground work, if properly carried out in combination with the judicious use of water, are not productive of unhealthy conditions due to dust. Boring holes beneath the horizontal is quite safe, using piston drills with the outside jet. Rise holes can be bored in perfect safety with dry head hammer telescopic feed machines, using the Clifton collector, or with axial water-feed machines, and boring pop-holes is practically a dust-free operation when using water supplied per medium of the Clifton collector as modified for this purpose.

Allaying Dust from Firing.

The real source of dust production underground is that caused by the firing of holes.

A sample of air taken immediately after firing a three-hole cut in a drive in one of the Johannesburg mines gave 86,000 particles per cc. (*vide* General Report, Miners' Phthisis Prevention Committee, par. 91).

Investigations have conclusively proved that dust produced in this way can be satisfactorily laid by the use of the water blast, an apparatus in which a stream of water is atomized by compressed air, so that the space adjacent to the explosion becomes filled with minute drops of water, which attach themselves to the dust particles and lay them. The following table shows the number of dust particles per cc. remaining in the air after the application of the water blast for 32 minutes. The tests were conducted in a stope—970, section H, Broken Hill South mine—by Mr. T. A. Read, and the figures obtained are comparable with the dust counts without the use of the water blast in the same stope :—

(A) Without Water Blasts.					(B) With 3 Water Blasts.			
Time after blasting in mine.	Average No. of dust particles per cc.	No. of Spots.	under 5 microns.	% in Suspension.	Average No. of particles per cc.	No. of Spots.	% under 5 microns.	% in Suspension-
5	36,029	5	95	100	11,738	6	100	100
32	17,551	6	95	48.7	2660	6	100	22.7*
47	12,866	6	97	35.7	2487	6	100	21.2
62	8343	5	100	23.1	1460	6	100	12.4
77	6946	6	100	19.3	1237	5	100	10.5
92	6808	6	100	18.9	1250	6	100	10.6
117	3530	3	100	9.8	879	6	100	7.5
122	3432	4	100	9.5	702	6	100	5.9

* Water Blasts Stopped.

In Test (A) no water blasts were used.

In Test (B) three water blasts were used to cover the face of the stope ; they were run for 32 minutes after firing.

The tests were conducted in a dead-end stope, 150 ft. long and 60 ft. wide, the only opening being an 8 ft. x 8 ft. crosscut at the end farthest from the face. Six holes were fired in both tests. In "A" test there was three times as much dust as in "B" test five minutes after firing. Thirty-two minutes after firing (when the blasts used in "B" test were stopped) there was 6.6 times more dust in "A" test than in "B." The total dust counts in test "B" seemed low, and were therefore confirmed by a duplicate test. Test "B" shows 702 particles of dust 122 minutes after firing, whereas test "A" shows 3432. Had the place chosen been a developmental end, the water blast would have better control, and lay the dust quicker; whilst had there been a ventilating current the dust would have been carried out into other parts of the mine. Results such as these show the necessity for cutting out promiscuous firing.

Reference to the figures of tests taken in the Broken Hill South mine shows that the three samples taken after firing from drives and crosscuts, when the blast had been on for 12 minutes only, gave results averaging 147 particles per cc. These three tests were made chiefly in order to experiment with varying quantities of air and water in the blast. Comparisons of resulting dust counts with those obtainable after firing in the stope section show that the water blast is a successful dust-allayer.

It is desirable to lay the dust at the point of origin if possible. There is a much better chance of doing this in development places than in stopes where the area to be dealt with is larger. The suggestion is put forward that every working face in all stope, should be supplied with at least one water blast, and that additional water blasts should be placed over the stope, winze, or other outlets, in order to catch the dust as it leaves the stopes and that the ventilating current should be sufficiently strong to quickly sweep the stopes clean.

The use of the water blast has one disadvantage, inasmuch as the air in the immediate locality will quickly become saturated with moisture, no matter what the temperature is; consequently, when a large number of blasts is used it is desirable to remove the humidified air from the mine as quickly as possible.

The type of water blast that should be used is a matter that has received considerable attention on the Broken Hill South mine.

The results of the following tests indicate that the best results are secured by the employment of a large air consumption blast, pointed in the direction of the ventilating current, for the following reasons:—

(1) For the same water consumption a much greater spread of blast is obtained, and there are no big drops formed.

(2) Much lower dust counts are obtained.

(3) Pointed in the direction of the air current, ventilation is assisted instead of retarded.

Three types of blast, herein designated as "A," "B," and "C," were chosen for test. They were first tested on the surface for air and water consumption by means of meters placed in the mains. The following results were obtained :—

Type.	Cub. ft. of Free air per min.	Gallons of water per min.	Remarks.
A. ..	20	2	Good blast, but did not carry far.
B ..	67	2½	Big drops formed near nozzle.
C. ..	133½	2	Very good.

In order to test the dust-allaying efficiency of these blasts, a dead-end drive underground was chosen, each blast being tried out as nearly as possible under similar conditions. The blasts were pointed towards the face, the dust samples being taken about 12 feet in advance of the blast—viz., at the point the holes were fired. The following statement shows the dust counts obtained :—

No.	Conditions.	Total Dust particles per cc.		
	Free Air used per min :—	A 20 c. ft.	B 67 c. ft.	C 133½ c. ft.
1	15 minutes after firing, immediately after blast stopped	2586	786	No spot.
2	20 minutes after	2540	2554	25
3	25 ,, ,, ...	1546	2405	147
4	34 ,, ,, ...	2405	1858	426
5	40 ,, ,, ...	2748	1752	No spot.

The result of this test was so strongly in favour of blast "C" that a check was carried out, which confirmed the result expressed above.

Further tests were conducted in a small sill floor stope on the 1270-ft. level, the only openings into which were an 8-ft. x 8-ft.

crosscut on the 1270-ft. level and an 8-ft. x 5-ft. winze from the 1170-ft. level. The course of the ventilating current was through the 1270-ft. crosscut to the stope and up to the 1170-ft. level through the rise. In the following test the blasts were so directed as to throw over the winze on the 1170-ft. level and against the normal direction of the current :—

No.	Conditions.	Total Dust Particles per cc.	
		Blast "A"	Blast "C"
1	3 minutes after firing, immediately after blast stopped	2493	836
2	15 minutes after firing	1493	56
3	20 ,, ,, ,, ...	3151	238
4	25 ,, ,, ,, ...	1231	831
5	30 ,, ,, ,, ...	368	1993
6	35 ,, ,, ,, ...	248	2665
7	40 ,, ,, ,, ...	152	2140
8	45 ,, ,, ,, ...	—	1398

The conclusions to be drawn from this test are as follows :—

(1) The combined effect of the ventilating current and the small consumption blast "A" was sufficient to clarify the air in 30 minutes after firing, but as the direction of the blast was opposed to that ventilating current there would be a certain amount of retardation ; further, as the stream of atomized water produced is relatively small, there is the possibility of dust particles getting through and being carried on to other working places in the mine.

(2) Blast "C" was so strong that the direction of the ventilating current was unused, hence the heavy dust counts after the blast was stopped and the ventilation had again become normal.

In the following test of blast "C" the blast was located at point Z in the accompanying sketch (Fig. 4) ,the samples being taken as indicated by the location of the numbers :—

The object in this arrangement, which is recommended as the best in dealing with dust issuing from stopes, and which, in the

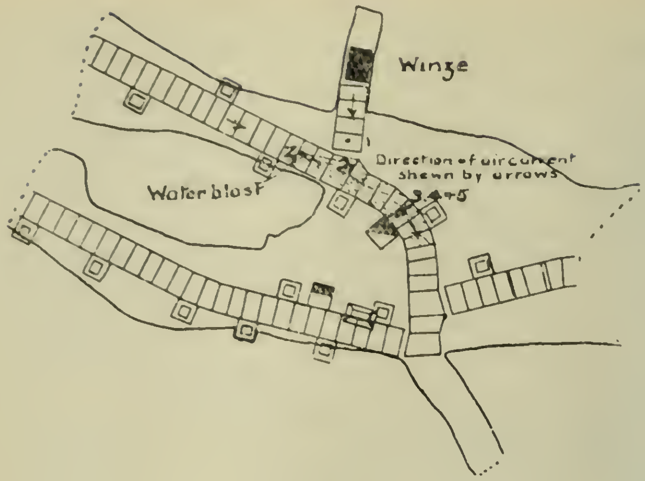


FIG. 4.

LOCATION FOR WATER-BLAST, 1170-FT. LEVEL. SEC. G.

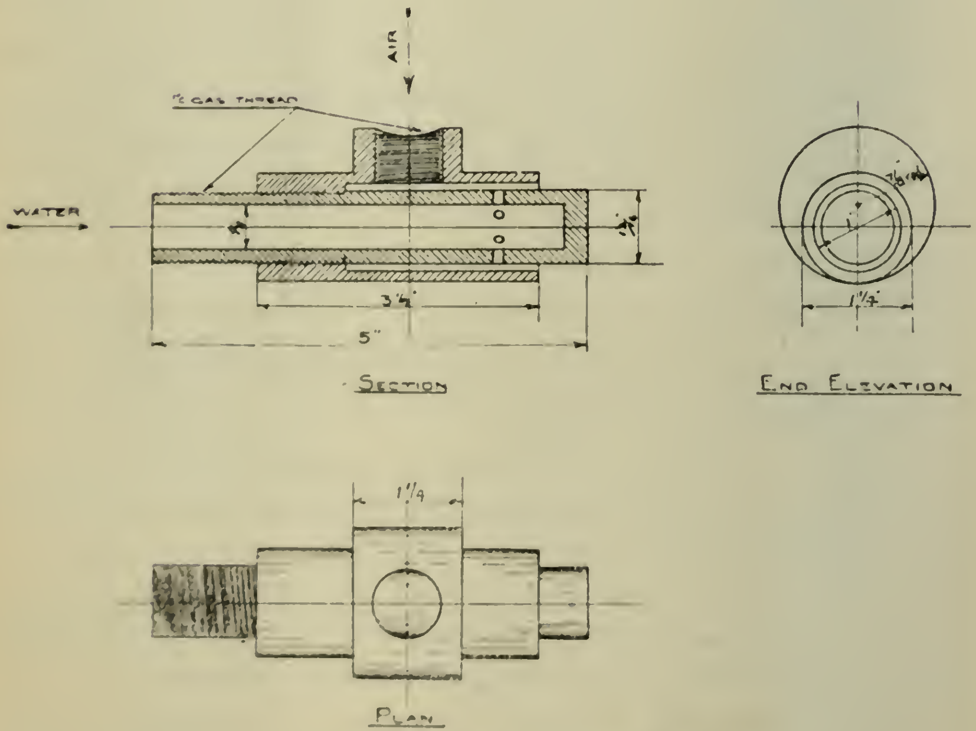
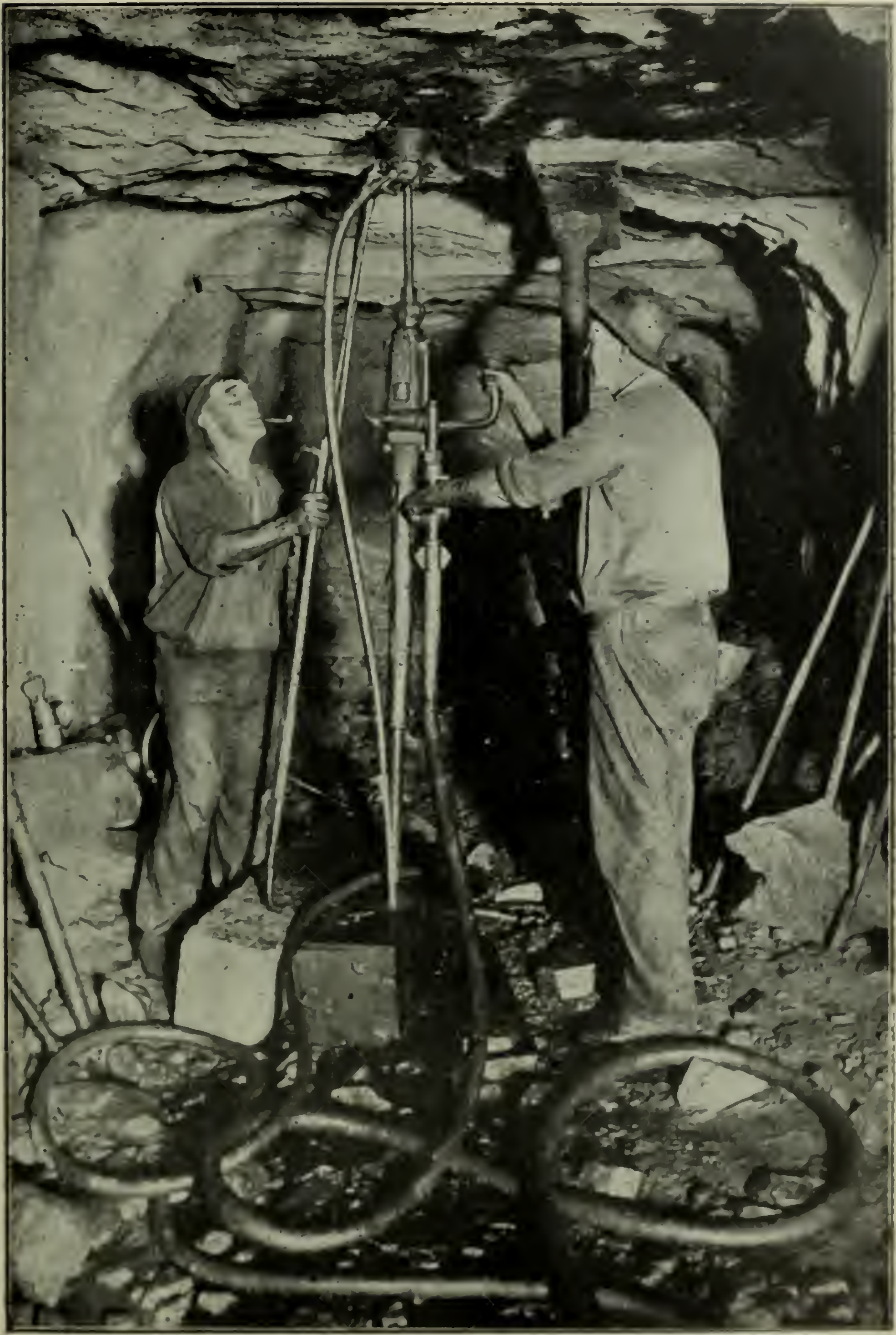
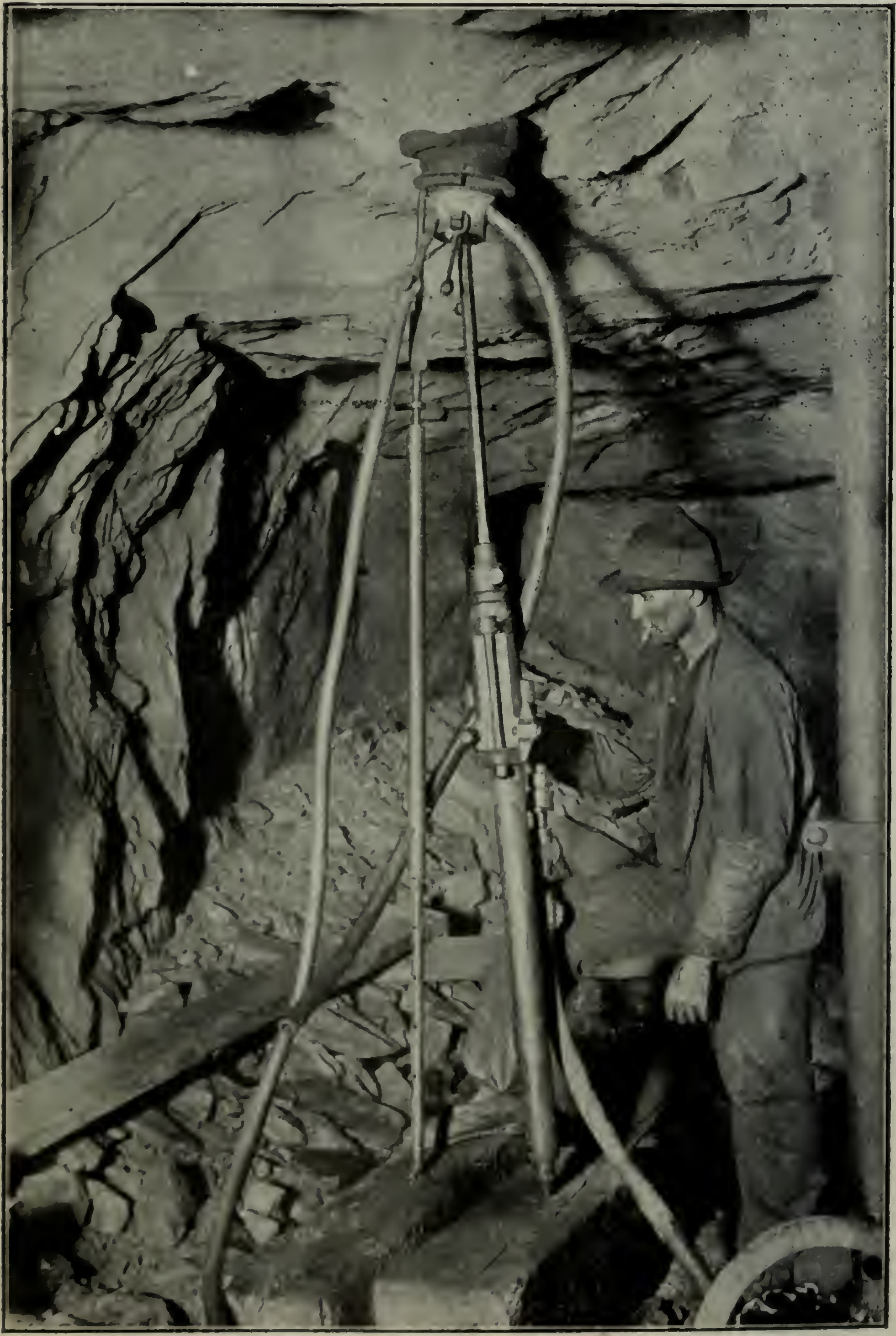


FIG. 5.

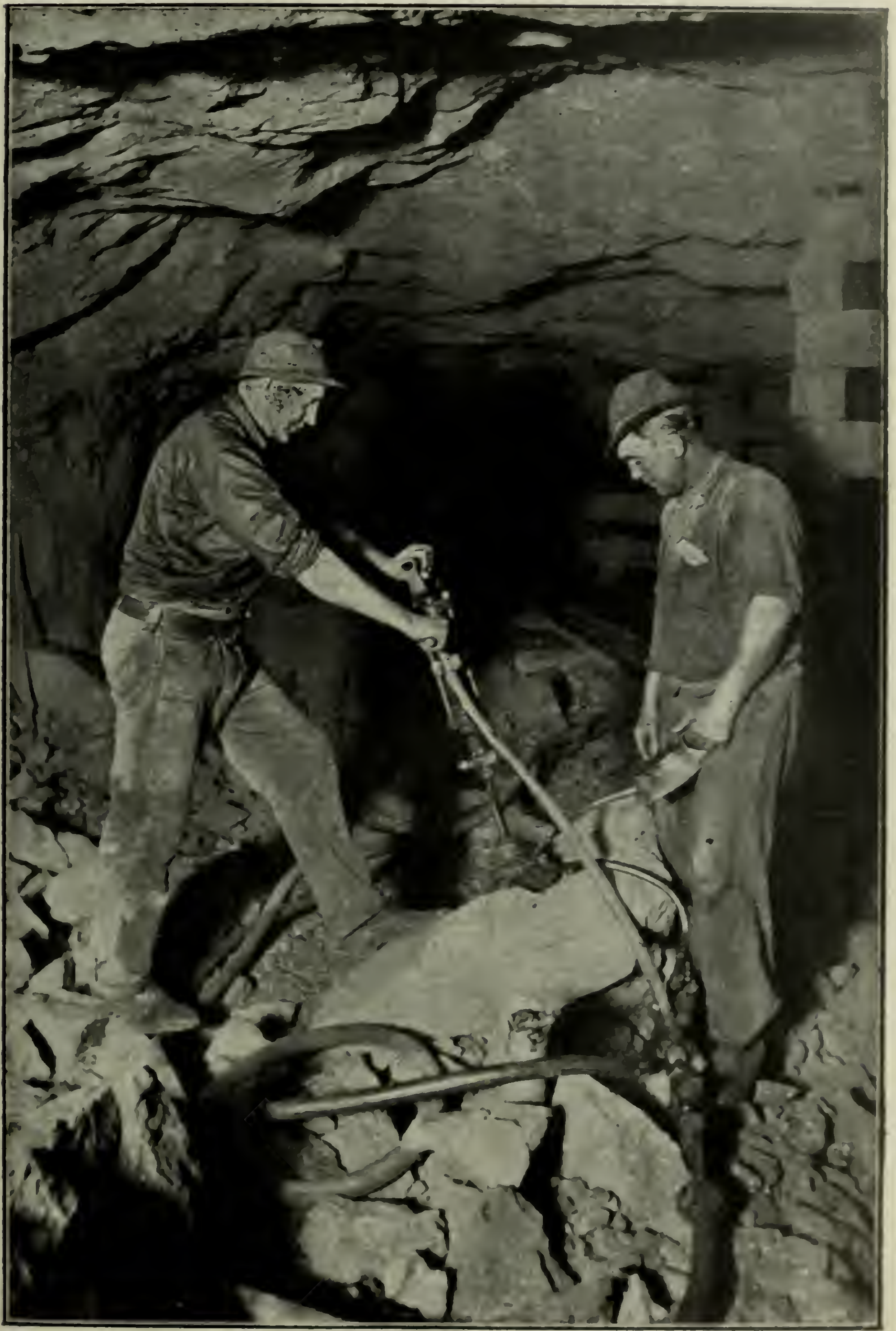
WATER-BLAST C.



Original "Clifton" for use in Rises, set up underground.



Improved "Clifton" for use in Rises, set up underground.



Original "Clifton" for use with Poppers, set up underground.

Broken Hill South mine, is used in conjunction with water blasts located in the stopes, is twofold, viz. :—

(1) To assist ventilation.

(2) To secure a good commingling of dust particles with the stream.

The gangway is filled with atomized water for a distance of about 100 ft. in advance of the apparatus.

No.	Conditions.	Total Dust per cc.
1	3 minutes after firing in air before reaching blast	Too heavy to count.
2	3¼ minutes after firing in blast	1062
3	15 minutes after firing, immediately after blast stopped	152
4	20 minutes after	No spots; few odd particles only.
5	25 ,, ,, ...	

Blast "C," which was designed by Mr. J. C. Cunningham, chief engineer of the Broken Hill South Ltd., is shown in Fig. 5.

DISCUSSION.

Mr. W. D. **Whiteman** said he had followed with considerable interest the very instructive paper read by Mr. Warren on "Mechanical Methods of Dust-Allaying," and he was sure they were indebted to him and also to the other members of the staff of the South mine who had assisted him, for the valuable work they had done on that most important problem, which had to be considered very seriously at the present moment in Broken Hill. The recent enactments passed by Parliament in connection with the incidence of plumbism and pneumoconiosis had thrown heavy burdens on the mining industry for the future, and, as the diseases were the outcome of the inhalation or ingestion of dust in different forms, preventive measures to combat their possible occurrence had necessarily to be studied. With regard to lead poisoning, medical men were not generally in favour of the opinion that it was contracted through working in sulphide ores; but the fact of the mines having worked carbonate ores extensively in the past had no doubt provided the legacy, the onus of which they are now called upon to bear. Concerning pneumoconiosis, its existence at Broken Hill was not conclusive evidence of the dangerous character of the dust in the mines in comparison with other mining districts. Miners came there from other fields, and might there have acquired the diseases, as their histories in a great many cases suggested. Still, as prevention was better than cure, and the causation of those diseases was held to be dust in a very finely divided state, it was a good thing that the subject had been opened up, in order to invite discussion, and he was sure Mr. Warren would welcome any criticism, even if it differed on some of the points involved. The chief points for discussion seemed to be the efficiency or otherwise of suggested methods for allaying dust produced in—

(1) Boring operations.
(2) Firing operations in development faces.
(3) Firing operations in dead-end stopes and also well-ventilated stopes.
(4) The efficiency of the konimeter as the determining factor in arriving at the results obtained.

There was another operation—the handling of broken material underground—that was productive of dust in a lesser degree, but he thought the methods of watering down adopted were shown to minimize danger from that source.

(1) Boring Operations.—The experiments in that direction on page 34, he thought, showed that the dust could be successfully laid, at the point of production, by the use of water jets on piston drills or by water internally applied through the drill steel to the cutting edges of the bit in axial water-feed machines. The comparative results obtained with the improved Clifton apparatus in rising and popping operations spoke for themselves as regards low dust counts; but in view of the recent controversy raised in South Africa as to the possibility of water-vapour marks being mistaken for dust particles in counting spots taken by the

konimetric method of sampling, it was possible that the merits of axial water-feed drills had been disparaged to some extent on account of fogging. The machines combined the one man one machine principle also in that class of work. In rising work, undoubtedly, the Clifton apparatus, if it could be accommodated to the successful boring of side and corner holes, provided extra comfort to the miner by enabling him to keep dry, and it also admitted of further use being made of large numbers of dry head-hammer drills possessed by the companies, which otherwise might become obsolete. The same trouble, however, was to be expected in enforcing the use of the Clifton as was experienced in the use of the water jet. (2) Firing Operations in Development Faces.—Those operations, to his mind, were productive of the worst conditions as regards fine dust that they had to contend with, because the very nature of the operations, often entailing continuous shift work, and embodying the out and round method of firing, as they did, brought the miner into more intimate contact with the dust than he would be if engaged in firing stope holes. The recommendation to have water blasts near development faces he thought desirable, if only from the point of view of clearing and cooling the end; but he would not care to accept the statement that all the dust particles produced in firing an end were allayed by passing through the blast. A great number might only be forced out of the working face and enter the ventilating current, or return later by diffusion to vitiate the end again. The tests given on page 44—trying out different types of water blasts—might seem to indicate the following procedure:—The smaller blast ("A") removed some of the dust contents by reason of the atomized water it conveyed and some by displacement due to the introduction of 300 cub. ft. of new dust-free air, after a 15 minutes' interval. Blast "B," by the introduction of 1005 cub. ft., removed more dust, which was probably returned after the lapse of 5 minutes by diffusion, when the blast was not working; and blast "C" set free 2000 cub. ft. of additional air, sufficient to fill a 10 ft. x 10 ft. drive, for 20 ft. back from the face, in 15 minutes. Although no dust count showed after the stoppage of the blast, dust gradually returned, until 426 particles per cc. were indicated 19 minutes afterwards. After a further lapse of 6 minutes no dust was present, which seemed hard to reconcile with the previous readings. Samples taken at corresponding intervals closer to the exit from the drive would prove whether that deduction was warranted, in view of the fact that in South Africa it was recommended that a series of blasts should be installed at intervals in drives and crosscuts exceeding certain lengths, to minimize the quantity of dust escaping. Certainly, if the dust were blown out of the development end and passed direct to the upcast, the object was achieved, but if it were drawn into other working places in transit any ill effect would have to be borne by other workmen. If the drive in question were less than 10 ft. x 10 ft. the introduction of the same quantity of compressed air would produce more pronounced effects. (3) (*a*) Firing in Dead-end Stopes.—Following the same line of reasoning, the experiment outlined on page 42—stope 970, section H—may be analyzed. If three high-consumption water blasts were used, of total capacity 400 cub. ft. per min., they would produce appreciable diluting or displacing effect in 5 minutes in close proximity to the face, in addition to that caused by the explosion, and in 32 minutes, in a stope 60 ft. wide by, say, 10 ft. high, they could fill the stope by replacement to a distance of 20 ft. from the face. These tests certainly did not show an increase of dust particles after the cessation of the blast, as in the case of the drive, except in one instance, at 92 minutes after firing, and the results achieved by 5 minutes of water-blasting at the point of sampling (which, he presumed, was close to the face) corresponded to those attained in about 50 minutes without the use of the blast. However, a duplicate set of samples could be taken simultaneously with the ordinary sample at a point, say, 50 ft. to 100 ft. from the face, to clear up that point. They know that compressed air, expanding rapidly after release, would reduce the temperature considerably in the neighbourhood of the face, and tend to displace the hotter and lighter air resulting from the explosion. (3) (*b*) Firing in Ventilated Stopes.—On page 45 the effect produced with the two water blasts of different capacities, working against the ventilating current, was explained by Mr. Warren as being unsatisfactory, and, without a knowledge of the velocities of the air currents or any corresponding readings taken in the stope below, and again at some point, say, 100 ft. or more in advance, in the gangway on the 1100-ft. level, it is difficult to say whether the small blast "A" in the first test did not give as good results in 45 minutes as were produced in 20 minutes with the larger blast, taking into account the retarding and accelerating powers of the two blasts in the respective tests. It appeared to him that the speed of the ventilating current in both cases contributed largely to the results. The high-consumption blast test (sample 2, taken in the blast) would be subject to the diluting effect of the air from the blast itself, and also to that of the additional purer air that would be drawn along the timbered gangway in which the blast was arranged—on No. 11 level. Samples 3, 4, and 5 were also taken at a point where both currents would combine, and he did not think the test could be called conclusive unless it could be shown that the blast was efficient as an extracting agent for fine dust. His meaning was that the velocity of the current might have been sufficient to sweep practically all the dust-laden air through the water blast before it was stopped. The only way to verify that would be by taking samples both in the stope and in advance of the water blast while it was in operation, due account being taken of the speed of the air current and its subsequent dilution, so that the same air leaving the stope might be sampled again on the other side of the water blast some minutes later, and the extraction noted. He noted that in South Africa blasts were only compulsory in development ends or in stopes that were stagnant or badly ventilated. He would consider the use of blasts of extreme utility if it could be shown definitely that the dust was not simply swept away by the ventilating current through the blast, with only portion of the dust allayed, into other parts of the mine. The increased humidity imparted to the air would be considerable with a number of high-consumption blasts operating in every stope, and they would place a high peak lode on compressors. At present, in Broken Hill, the air passing through the working places approached the saturated state, and, in an endeavour to obtain complete elimination of the dust, they might reach a stage where the temperature and humidity would affect them more adversely than at present unless they were able to miantain an abundance of ventilating current to combat its effect. (4) Efficiency of Konimeter.—With regard to the konimeter as an effective dust sampler, South African practice seemed to have decided against that instrument as a reliable indicator of true dust in air, and there they now place more reliance in the gravimetric method. The two chief reasons seemed to be diversity in counts of the same samples by different experts and the difficulty in obtaining a full count in one operation with the apparatus. Another reason was mentioned previously with regard to water-feed drills, where water-vapour marks might be taken as dust particles. That error, however, would be on the safe side by tending to a higher count. The question of counting in regard to Mr. Warren's tests might not matter, as the counts probably would all be done by the same man, and would be comparative. With similar tests on different mines discordant results might occur. In conclusion, he trusted that Mr. Warren would not feel that he (Mr. Whiteman) had set himself out purposely to pick loopholes in the paper. He had only raised a few points that were doubtful to his mind, and which discussion might have the effect of clearing up. Mr. Warren and his associates in his work on the South mine were to be congratulated on the very excellent paper, which was the embodiment of an enormous amount of detailed experimental work.

Mr. H. H. Carroll said most of the experiments referred to in Mr. Warren's paper were conducted on the South mine, and for that reason he preferred not to discuss the mechanical means of dust-allaying, but would like to make a few brief references to the methods employed in dust-sampling. Although particles 5 microns and under were considered as dangerous, it had been the exception to find in the lungs of deceased persons particles averaging more than 1.5 microns, and it was with the sampling of air containing these small particles that they were most concerned. Mr. Warren's paper showed the results of sampling, using the konimeter method. Although that method was not altogether satisfactory, they were of the opinion that it did give a very fair indication of the quality of the air in so far as the observer could readily distinguish the particles under and over 5 microns in diameter. That division might be satisfactory, but it made no distinction between the effect on the lungs of particles 1 micron in diameter and particles 5 microns in diameter, although the latter weigh 125 times as much as the former. For a similar reason the gravimetric method could not be considered as absolutely accurate, because a sample containing particles 4 microns in diameter might show a low count and yet weigh many times as much as a sample containing particles only 1 micron in diameter, and by count showing a much greater quantity of injurious dust. It would seem that the best results were obtained if the two methods were used in conjunction, but either gave an indication of the quantity of dust in the air, and that was really the main question. Since writing his paper Mr. Warren had an opportunity of collecting samples by both methods, and he was, no doubt, prepared to submit some of the results. It would be interesting to hear medical opinion as to whether the degree of silicosis produced depended in any way on the mass of the particle inhaled. That was rather an important point, because they found that, as a rule, internal water-fed machines produced much finer dust than reciprocating machines. For the purpose of comparison, the konimetric results had been compared with the arbitrary standard adopted by the South African Committee. Whilst it might be advisable to maintain that standard, it was hardly a fair comparison, because of the different nature of the dust produced in Broken Hill and in South Africa. In the first place, the specific gravity of the material mined was approximately 1.5 to 2 times that of the South African material; and secondly, the insoluble content—*i.e.*, silica and silicates—would vary considerably. The insoluble content of a number of samples obtained in Broken Hill showed, on the average, 40 % insol., whereas, with samples obtained in South Africa, it would be safe to assume an 80 % insol. content. Owing to the varying conditions met with underground, counts obtained from any particular operation showed a considerable difference, even if taken at short intervals of time. Some of the conditions affecting the counts were :—

(1) The exhaust from machine drills would cause eddy currents, and the counts would vary according to the position of the instrument.
(2) Rate of drilling and character of rock drilled. Hard rock will, as a rule, produce more dust particles than soft rock.
(3) Quantity of air circulating. The larger the volume the more the dust was diluted.
(4) Humidity of the air. The low counts obtained in return airways was probably due to the precipitation of the dust by the saturated air.

It was fairly obvious, however, from the figures submitted, that it was necessary to keep all working places damp. That was, perhaps, a disadvantage, in that the air in the mine would become saturated, but, provided the temperature of the air was not excessive, that did not appear to be a disadvantage. H. J. Ireland, in a recent paper on the Kata thermometer, published in the *Journal of the Chemical, Metallurgical, and Mining Society of South Africa*, stated :—" It is possible to keep a man reasonably cool and comfortable working in an atmosphere of 85° F. wet and 86° dry, dew point 84.4°, provided the movement of the air current is 380 ft. per min." It was not suggested that that was an economical speed for an air current, but was intended to point out that the degree of humidity permissible was governed a great deal by the speed of the air current.

Mr. T. G. Hanton thanked Mr. Warren for affording an opportunity for the discussion of the whole question of dust-allaying. That subject was of much concern to those engaged in the mining industry at Broken Hill, and it was of great moment to those charged with the administration of underground operations. It was unanimously agreed that the process of underground exploitation was conducive, in some of the stages, to the production of dust in varying quantities. The effect of that dust upon the health of men exposed to it over considerable periods apparently depended upon the composition (and, accordingly, the physical characteristics) of the dust particles. Professor Collis. he believed, had recently stated that, whilst coal-dust was regarded as quite innocuous, that from a mixture of ganister and fire-clay was equally so, whereas the dust from a mixture of ganister and limestone may be regarded as deadly. He understood that Mr. Warren, in his contribution, assumed that a standard of dust-prevention was desirable locally, equally as high as had been considered necessary in the phthisis mines of South Africa. His comment on the various proposals put forward by Mr. Warren were based on that assumption, and any criticism offered or alternative methods suggested were not made with any disregard to the possibly deleterious effects of local dust. Any consideration of its degree of injuriousness fell outside the scope of the paper. A maximum of 5 microns was generally accepted as the dangerous limit of size of dust particles. It might be interesting to note that quartzite particles under 100 microns were invisible to the naked eye. Regarding the sampling and estimation of dust, he noticed that Mr. Warren's results were based on samples taken by the Kotze konimeter. Personally, he had for some time regarded that instrument with suspicion, encouraged only by the minority report of the South African Commission, 1918. However, he had recently noticed, in the report of the South African Chamber of Mines (Standing Committee on Dust Sampling), evidence on the term of reference, "The steps taken for the prevention of the disease and whether any improvements are possible in that direction," November, 1920, a general condemnation of the Kotze konimeter and its various modifications, except for qualitative purposes. Those views were opposed by the Government Mining Engineer, Sir Robert Kotze, but, nevertheless, seemed fairly convincing. They concluded by stating:—"The konimeter sample is small, instantaneous, and local; it is difficult to be sure that one is counting dangerous dust, and the personal factor in the counting renders results of doubtful value." They advocated the use of the gravimetric method, combined with the konimetric, as affording an indication of the noxiousness or otherwise of the place where the sample was taken. He would like to quote in full, however, one of their remarks concerning the konimeter:—"It has been noticed for some time that when konimeter samples are taken in places where water-fed machines are creating a fog, extremely high dust counts were obtained; further, in examining some shafts where sinking was in progress and where a constant stream of water was falling down the shaft, it was found that, while the gravimetric samples would vary considerably, yet the konimeter samples showed practically uniform results—*e.g.*, gravimetric average, 6.2 mgms., count 2464 part.; 23.8 mgms., count 2387 part." Experiment showed that water vapour produced markings on the slide similar to the small spots caused by dust particles, and led to the conclusion "That when a konimeter sample is taken in a mine where there is a large amount of water vapour, the water vapour is drawn into the konimeter with a high velocity, and pits the vaseline. These small spots appear under the microscope as if they were particles of dust, and if real particles of dust are mixed with them it is impossible to discriminate between the real and the unreal. This is probably the explanation of some of the high results obtained by the konimeter." He would like to ask Mr. Warren whether that factor would, in his opinion, have any bearing on the apparently somewhat more favourable konimeter counts obtained with the Clifton apparatus as compared with axial water-fed machines. The committee also stated, when considering the question of Leyner drills and the dust counts obtained from them by both methods:—"In the light of the above results" (*vide* report) "it seems that the suggestion to abolish the Leyner drill is a thoroughly reactionary step, seeing that it makes no more dust than any other drill, and is a much quicker machine." He asked the indulgence of members for having quoted so extensively from this 1920 South African report, but he thought the fullest possible discussion of the subject was desirable. Further, he thought that the facts disclosed should be something in the nature of a warning to local mining engineers. The konimeter was developed in South Africa, used as a standard in 1917 and 1918, and now, in the light of further experience, the committee in 1920 was recommending, in effect, that it be discarded for quantitative work. From the same source came an early recommendation for the abolition of the Leyner drill. These machines were now in greater favour than other types. It appeared to him exceedingly probable that a similar reaction would occur with respect to the earlier South African recommendations in other respects—*e.g.*, water blasts and the indiscriminate use of water underground. Therefore, he thought Broken Hill mining men should be rather chary in the matter of adopting any of those recommendations without a very full consideration of the effect upon local conditions, and should rather evolve their own methods to meet their particular requirements. Before considering Mr. Warren's remarks on the subject of water blasts, he would like to say something on the matter of the Clifton dust collector for rising and popping. He, like Mr. Warren, was at one time rather a warm admirer of this apparatus. However, early in this year he assisted in testing it under actual rising conditions, holing through a rise on the Zinc Corporation Ltd. The rise was 6 ft. x 4 ft. vertical, and started from the back of an open stope. Starting with the best intentions to use the apparatus right through, they discarded it before the second cut was bored out, and reverted to the use of the outside water jet. The outfit used by them had all the latest modifications — sponges, movable bottom, and adjustable stand, as illustrated in Mr. Warren's paper. The rise machine used was an Ingersoll CC 11. The following were the points which, in his opinion, would count very much against the use of the apparatus for rising:—(1) The back was generally more or less uneven; even with the sponges it was difficult to secure a dust-proof joint. About 16 holes were required to bore out the rise ; so, even with the best of luck, a bad irregularity was bound to be encountered by some of the holes. Without a good joint the quantity of dust escaping over the top of the sponges was extremely heavy. (2) For side and corner holes it was found impossible to start a hole as close to the side or corner as desired, on account of the space taken up by the apparatus. That defect became apparent at once when the rise advanced above the back of the open stope. (3) Under the best of conditions it was difficult to collar a hole exactly where desired, and, unless a vertical hole, to pitch it in the required direction. In any inclined holes it was found that the drill pressed slightly against the bottom plate, and the general tendency was for the hole to straighten up. It would obviously be most unsuitable to use a separate outside water jet for collaring purposes, as the already considerable amount of gear would be added to, and the operators would likewise be well wetted. (4) The space in a rise was generally confined ; elaborate staging at the top was not usually necessary—merely sufficient to form a footing for the operator, the machine, and the sharp steel. To provide support for the Clifton stand a much better arrangement of staging was required. The time occupied in rigging the Clifton so that it would not interfere with the rotation of the machine handle was considerable. (5) The various iron parts on the stand, screw thread, &c., required very frequent oiling to prevent them rusting tight. That could, of course, be obviated at increased expense by brass parts. (6) Even under sympathetic treatment the wear on some of the parts, notably the sponges and the rubber sleeve through which the drill passed, was fairly rapid. The actual cost of replacement was trifling, but, once they were out of order, the apparatus lost all the virtues claimed for it on the score of dryness and freedom from dust. Unless supervision were very good, the miner would probably continue using the apparatus, although not in order, rather than walk down his rise and lose time in getting a new part. (7) In changing drills the operator was very fortunate if he kept dry. A certain amount of water was held up in the dish. When the operator reached up and unclamped the bottom plate the accumulated water ran down his extended arm, and probably finished in his boots. (8) The water played only round the collar of the hole, and did not extend into the hole. Drills were therefore liable to stick, especially in good boring material, and might thus cause the abandonment of the hole. Also, the drill became very hot, and thus more rapidly lost its cutting edge. (9) In an inclined rise, he should imagine that the difficulties of rigging the apparatus, collaring and pitching holes, would be considerably enhanced. He would like to ask Mr. Warren whether the apparatus had yet been used in actual rising work on the South mine. Regarding the Clifton popper, it appeared an excellent contrivance, with only the slight disadvantages that the popper man could not see where he was collaring, and could not steady the drill with his foot when collaring. On the Zinc Corporation, in November, 1920, they introduced a very simple form of apparatus for popping. Considerable difficulty was experienced in enforcing their use, partly due, doubtless, to the idea that it rendered popping a one-man operation, as Mr. Warren properly contended it was. When used, the treatment meted out to them was certainly pretty harsh. He would like to ask Mr. Warren whether any difficulty had been experienced in respect of popping with the Clifton being a one-man operation. The popping apparatus, as illustrated by Mr. Warren, was, he fancied, only suitable for machines such as the Waugh 22P, using steel without a shank. On the Zinc Corporation these machines had been discarded for popping in favour of the slightly heavier and faster boring "jackhamer" type, and so the apparatus he illustrated would not meet their requirements, as the steel was all shanked. As their preference was for the "jackhamer" rather than a non-rotating popper, so their tendency, in eliminating the outside water jet, might be more on the lines of the introduction of axial water-fed machines for popping work. From a dust-allaying point of view their konimeter counts showed them to be effective, and they were certainly a one-man machine. There were, however, certain difficulties to be overcome with them, and they had not yet tried them on that work. He merely mentioned that development to show that an arrangement which might quite well meet the requirements of one mine was quite unsuitable for those of another. He noticed that Mr. Warren, on page 41, referring to rise machines, mentioned axial water-feed drills of the Ingersoll Leyner type. Did he mean the type 18A, or the later 148 and 248, or a telescopic machine with axial water feed? It was generally agreed that blasting operations caused the bulk of underground dust. Opinion varied as to whether it was desirable and possible to allay that dust by the application of water actually at the point of production. It appeared certain, however, that, except in particularly favourable instances, dust could not thus be effectively dealt with, and that, unless ventilation was effective, the desired result could not be attained. From actual experience of water blasts in stopes, and more particularly the wider stopes, they arrived at the conclusion that the only means to allay the blasting dust was to catch it at its outlet from the stope in every case where it would traverse any other working places before reaching the main upcast. Allaying in the stope itself appeared quite impracticable, and it was decided that the use of any water blasts in the stopes themselves was useless. The proposal, therefore, was by means of an effective ventilating current to sweep the dust-laden stope air direct into the main upcast wherever possible, and, where that could not be done, to remove the dust as it emerged from the stope at certain selected outlets. He referred Mr. Warren to the latest South African report for support in the contention that dust could not be effectively laid in stopes by the application of water in the stope itself. Mr. Warren apparently realized that fact so well that he (the speaker) was rather at a loss to understand why Mr. Warren should propose, as he said, "to place at least one blast in the stope itself." If it were not going to be effective, why undertake the cost of the installation? Permanently connected blasts, pointed in the right direction, could be fixed at all possible outlets, and these could be turned on and off as a matter of routine by any of the present staff. In the case of a water blast in the stope itself, it must keep moving all the time as stoping progressed.

It must therefore be a flexible arrangement, and meant hose connections, in all probability. It appeared to him that the arrangement and maintenance of those would entail a considerable addition to the pipe-fitting gang. He would like to ask Mr. Warren, Would he propose that the miners should be responsible for arranging and using those blasts before firing, or did he advocate separate dust officials for such a purpose? Usually, too, popping operations were being carried on at some distance behind the stope face. Did he propose a water blast in the stope to try and allay the dust from pop-firing? Granting that the stope blast were effective, would not the dust be stirred up again in the stope by the ventilating current? He was in complete accord with Mr. Warren regarding development places and all dead-end stopes. These were all cases in which a water blast might be effectively used, and some benefit derived from their installation. He did not, however, think that Mr. Warren had sufficiently stressed the disadvantage he mentioned concerning water blasts—*i.e.*, the rapid humidification of the air due to their use in large number. That would appear to provide another argument against Mr. Warren's proposal for the use of water blasts in stopes. The effect of moisture in air on underground working conditions was most important. The South African Commission, November, 1920, stated:—"In very deep mines, where high temperatures, combined with saturated air, are likely to become a menace to health, it may be advisable to control the addition to moisture in order that advantage may be taken of this evaporation to produce local cooling effects." Dr. Leonard Hill, contributing to the discussion on a paper read by Mr. E. H. Clifford before the Institution of Mining and Metallurgy (Bulletin No. 199, April, 1921), on "A Scheme for Working the City Deeps Mine at a Depth of 7000 Feet," stated:—"The wind was the most potent factor in cooling us; the wet Kata showed the influence of wind and humidity"; and later again referred to the importance of moving air and the possibility of keeping cool by sweating as long as the air was dry and moving. In a report presented to the Institution of Mining Engineers, April, 1920, the committee appointed to consider the working of deep mines in England stated, amongst their conclusions :—" The hindering effects on men of heat in deep mines depend, not on the temperature of the air, but on the wet bulb temperature and the degree of stagnation of the air." A little earlier they stated :—" Thus the problem of underground temperature control seems to resolve itself into that of adequate ventilation planned with a clear conception of what is required in order to prevent loss of the miner's working capacity, and not merely to obviate trouble from fire-damp or vitiation of the air by other gases." To such an extent was that committee prepared to go in the effort to keep the wet-bulb temperature from rising, with a corresponding disadvantage to working capacity, that they recommended stone dusting rather than watering for dealing with coal dust, thus keeping the air dry as long as possible and obtaining the maximum benefit from the cooling due to evaporation of moisture from the working faces. That might be regarded as a digression from the subject of Mr. Warren's paper, but there was no doubt that the extensive use of water blasts was going to make for saturated air in the workings. Thus, unless very careful consideration was given, in addition to the financial burden imposed upon the industry by their introduction, the use of numerous water blasts underground apparently might adversely affect other factors regulating underground conditions. Very much could be said on the subject, and he trusted there would be a full discussion on it. Regarding the type of water blast suitable for underground use, he fancied that almost every local mine could produce several types, each different from those of the other mines. Referring again to the November, 1920, South African report, perhaps *ad nauseam*, it stated :—" Doubts have recently arisen as to the advisability of using certain types of atomizers. Some of them seem to be too efficient in breaking up the water into minute drops. The question is being investigated." With regard to the air consumption of the various types of blasts, it appeared to be a matter of whether the extra power required for the higher consumption blasts was justified by increased dust-allaying efficiency. He considered that the increased fuel cost would be considerable, but that was a matter more for the engineers to give a ruling upon. With compressed air at 6d. per 1000 cub. ft. of free air, the "C" type of atomizer described by Mr. Warren would cost 4s. per hour each to run. He would like to hear some further discussion on that point. He thought that just about concluded his remarks for the present. None of his comments had been made in an attempt at destructive criticism merely. Every local mine was at present facing those problems, and an interchange of ideas could not fail to be mutually beneficial.

Mr. F. Voss Smith said he intended to comment upon the proposed introduction of water blasts, but the other speakers had pretty well covered the ground. He noticed that Mr. Warren used three blasts in one of the stopes to get results. Multiply the rock-drills by three, and the air consumption was going to be more than the compressor capacity. The idea of using one blast in a wide stope with a very big displacement of air when the holes were fired appeared to be absolutely hopeless.

Mr. Warren, in reply, said that he agreed with Mr. Smith and the other speakers that one water blast in a large stope had not much hope of allaying dust in that stope, but a big blast, such as type "C," had some hope of doing it, provided care and attention were directed in its arrangement. He said that if the blast were placed parallel to the face of the stope it would have to be a pretty wide stope that it would not cover. One of the chief uses, he thought, for water blasts in stopes was not so much for laying dust after explosions, but for turning on occasionally to keep the accidental dust in check. He said the blasts should be also arranged at the exits or outlets from a stope.

Mr. Smith, continuing, said in placing the blast so that it would deliver parallel to the face it would be a comparatively narrow curtain, and a big volume of air going through that curtain would not have the best opportunity of doing its work. It seemed to him that in using the blasts constantly the amount of water produced must become a nuisance.

Mr. Warren said that it was rather a big subject, and he expected to have an opportunity of replying later.

Mr. Smith remarked that, in connection with the Clifton apparatus, he would like to ask whether the choking of the small holes had been frequent or not. It had always struck him that there was no provision for cleaning.

Mr. Warren said that the hole was not very large, but it would be examined every time the steels were changed.

Mr. Smith asked how they could be freed if choked.

Mr. Warren replied that no bother at all had been experienced on that account.

Mr. E. K. Hall said he had to congratulate Mr. Warren on the paper he had presented, which expressed very clearly the results of a lot of work done by him and others concerned with it also. He did not agree with everything in the paper. As to dust-allaying by water blasts: In the development faces he thought that Mr. Warren had quite proved his case, because there was not the slightest doubt that in the future it would be considered a necessity. With water blasts in the stopes, however, he could not agree. Of course, they had on all the mines tremendous stope rooms, and the concussion of the firing immediately sent a wave right through that air, which in the ordinary way was fairly stagnant, and the dust all over the place was beyond the power of any water blast. One or two had suggested the use of the water blast at the outlet of a stope. That would be effective to a certain degree, and would prevent fine dust from getting away into other workings; but, from his experience, one of the most difficult things had been to prevent the air being saturated, and there was no doubt that the workers' efficiency depreciated enormously in saturated air, as Dr. Chapman had shown them, especially if the air current was not very rapid. They must remember that South African experience had shown water blasts to be quite ineffective in large stope places. Broken Hill ventilation in big stopes was not adequate; it was very difficult to get direct air current through them. They should follow the coal mines procedure regarding currents more than they did. Auxiliary fans were also going to help for local districts. They should be able to use the hour between shifts for improving ventilation. If they could get a decent current through the stopes, surely they could get the fine dust out of the mine between the day and the afternoon shifts in that hour. Of course, there was ample time after the afternoon shift, on account of the reduction in shifts. The odd stope holes had to be fired at the end of the shift. That was worthy of investigation. He asked if the dust were caused by the firing of a pop? or in other words, was the amount of ultra-fine dust anything like so much as the same dust fired from a development cut? He did not think so, because the development cut had a tremendous power, and acted more as a wedge. He thought they should discard efforts to make the water blast effective in the big stopes in favour of the ventilation problem. They would then have a hope of keeping the mine air well under the saturation point, and that would mean more efficiency amongst the men.

Mr. C. H. J. Clayton also congratulated Mr. Warren upon the delivery of his paper on "Mechanical Methods of Allaying Dust"—a subject which was of so much immediate interest at the present time, not only in Broken Hill, but in South Africa, Great Britain, and all mining centres where any depth had been reached. In the results from firing obtained under working conditions prior to May, 1919, no velocities of air current were given in the stopes, which might be dead-end, similar in conditions to those of a drive. A silica particle of 3 microns fell 7 ft. through still air in 33 minutes; of 4 microns, in 19 minutes. It was difficult to count dust under 3 microns, and it would appear that the stopes were not truly representative of Broken Hill with a through air current. Also, in the samples quoted, No. 1 showed 772 particles per cc., whilst No. 2 showed 3000 odd taken when the men returned, which, he presumed, was about 30 minutes after. Nos. 3 and 4 were similar to No. 2. He asked whether the greater number of particles in No. 2 was due to the stirring up of dust which had already settled. The following experiment would demonstrate that dust was stirred up :—If a sample for dust were taken in a dead-end crosscut where water blasts had been previously used, showing a clear slide, then a water blast turned on, an immediate sampling without giving time for settlement would disclose large quantities of dust. Dealing with the Clifton apparatus, some tests in January, 1921, already described by Mr. Hanton, who carried them out, were instructive. His working time analysis was rather interesting. The ground was easy to bore, but difficult to shoot. Total hours worked, 105.5. Working time divided into percentages showed :—

	%
Boring	18.6
Rig and unrigging, Clifton apparatus	12.8
Steel delays	2.9
Machine delays	1.2
Barring down	8.7
Bulk building	18.9*
Taking in tools	1.8
Pipes and hose connections	3.3
Charging and firing	11.6
After firing delays	5.7
Lamps, surface delays, &c.	12.1
Miscellaneous	2.4
	100.0

* The rise was difficult of access in the back of a leading stope.

Both operators were in a mess whilst using the Clifton, owing to rough ground not forming a decent jointing surface, as already described by Mr. Hanton. It was regarded as unsuitable for rising, and they had since then been trying out water-fed stopers, which seemed to offer a more satisfactory solution of the difficulty. A reference was made to cutting hitches in timber work with the popper modification ; he presumed these were only vertical hitches, and not in the walls. They also tried out a popping device on somewhat similar lines for suppressing dust, but could never keep them in use. The men were antagonistic, never denying the fact that they would keep dust down, but that they were not needed. The less one had to rely upon the employee underground the better. A statement was also made that the apparatus made the employment of an additional man unnecessary. He asked if that had been proved. The secretary of the local union, during the short time they were producing ore, repeatedly stated that he (the speaker) was the only manager on the field trying to make one man work a popper, and that everybody else worked two men to a popper. Then, in the official union newspaper, an advertisement was inserted on 9th March, 1921, to the effect that all men were forbidden to work any machine single-handed, be it "Long Tom," "jackhamer," or popper. In regard to rise work, a self-rotating stoper, water fed, was the ultimate object. He did not think the Ingersoll Leyner was meant for rising. Again, in allaying dust from firing stope 970, section "H," assuming that the three water blasts were of the "C" type mentioned later, they would use 400 cub. ft. per minute and run for 32 minutes, using 12,800 cub. ft. of air; the quantity of water—64 gallons—was quite sufficient to saturate a big volume of air. One pound of water highly atomized would densely fog 560 cub. ft. of air. If the stope were 9 ft. high and the capacity 81,000 cub. ft., 64 gallons of water would fog 358,400 cub. ft. He asked if there was a very big percentage of dead-end stopes in the Broken Hill mines, or was that quoted as a special case? It was stated that if there had been a ventilating current the dust would have been carried out into the mine. He suggested that it would have been under better control, as the three later samples from drive and crosscuts 12 minutes after firing gave only 147 particles per cc. The statement was made that it was desirable to lay the dust at the point of origin, if possible. In the case of a stope, was this dust not stirred up again at every firing? Considering the time of settlement of particles, it seemed to be a certainty that they would be again stirred up when the water blasts had gone forward with the face of the stope. He quite agreed that water blasts should be placed over winzes or other outlets from stopes when the outgoing stope air had to traverse a long succession of working faces and the velocity of the current was low; but he entirely disagreed with the suggestion that every working face should be supplied with at least one water blast. In stopes such as 970, section "H," where three water blasts were used, would one be of any particular benefit? It was always troublesome to keep water and air pipes close to the firing zone, and the popping—had not that also to be covered? They were some considerable distance back from the stope face with the present method of working. In the latest report from the South African Standing Committee on Dust Sampling, page 4, it is said:—"In open places, however, such as stopes, the use of a water blast after firing is useless. Water screens have been tried, but have not accomplished their object to any important extent." The South African Committee lay down a rule (on page 3)—"That water blasts shall be used in developmental ends, and also in every working place where there is no through ventilation." As far as developmental ends were concerned, conditions of areas to be covered were similar, but there was absolutely no comparison between the Broken Hill huge stoping areas and those of South Africa. Broken Hill was mining at comparatively shallow depths compared with South Africa, and must look to itself for the solution of its problem. The disadvantage of humidity was pointed out by Mr. Warren. Dr. Haldane had laid it down that in entirely still air, with the wet bulb at 78°, efficient work was impossible, and all the physiologists seemed to hold the view that a high moisture content was the factor to be avoided if possible; if not possible, other means of cooling the human body must be adopted, such as movement of air. On page 19 of the South African Standing Committee's Report it was said, "Temperature and humidity may have some relation to the incidence of phthisis," and the tendency all over the world was in the direction of keeping the underground air as dry as possible. In South Africa speedy means of combating silicosis had to be found, as their records would show. On page 86 of the Select Committee's report of 1916 they read:—"Out of 3136 whites actually at work, 26.1 % were found to be suffering from definite silicosis, while an extra

5.5 were probable, but doubtful. Of the 26.1 %, 21.7 % were early cases, capable of sustaining a fair amount of exertion without much effort. No account is taken of those who relinquished work on account of the malady. Of the affected men, 48 % were rock-drill men, compared with 32 % who did not use the rock-drill, and the worst cases were rock-drill men." Out of 6242 men examined at Broken Hill to date, 169 have been adjudged suffering from pneumoconiosis, 96 from pulmonary tuberculosis only, and 99 from the two combined, or a total of 364 cases. They might disregard the 96 cases of pulmonary tuberculosis only, which gives them about 4.3 % of cases possible in Broken Hill. If they could examine the ages of that 4.3 %, and their previous mining histories, they would see the difference between the Broken Hill case and that of South Africa. Some of the Western Australian mines, now shut down, had been silicosis producers. That also applied to the Victorian mines. The problem of underground health seemed to be directly concerned with ventilation, and the proper method of dealing with dust and noxious gases was to sweep them right out of the mine by the shortest possible route. It would not be surprising if physiologists soon determined that expired CO_2, with a definite temperature and humidity, lay at the root of most of the ill-health underground, by paralyzing some of the tissues whose functions were to remove deleterious substances from the body. He thought they were to be congratulated upon the general health of their employees, especially when they looked around at the employés' ideas of a home and the manner in which they disposed of their surplus pay. He thought that any other industry would consider itself particularly lucky to have the same record as Broken Hill. They were much indebted to Mr. Warren for his paper, and trusted that his example would be followed by the reading of further interesting papers.

Mr. T. A. Read said that he had had a little experience in connection with the problem of mechanical dust-allaying. At the end of 1917 and the beginning of 1918 he was asked to co-operate with the underground department, Broken Hill South mine, with a view to looking into the dust question and methods for determination. At that time they had procured copies of various reports from South Africa and U.S.A. upon dust, and it was quite clear, upon looking through the various devices and methods for the determination of dust, that Broken Hill was quite a different problem to South Africa and South Missouri (Jopalin district). In South Africa, roughly, the percentage of insoluble matter was 95 %, with 4 % pyrite; in the Jopalin district the insoluble was 96 to 99 %; and in Broken Hill, roughly, 50 %. The gravimetric method of determining dust after collecting by sugar tube was therefore not applicable to Broken Hill for accurate work, because of the difference in the chemical composition of the dust from blasting and boring operations. Ignition of the dust caused elimination of sulphur. The method of arriving at the number of dust particles by taking the dust collected in the sugar tube, dissolving in water, and taking a portion on a hæmacytometer cell, was useless for dust from boring and blasting operations, on account of the small quantity of oil atomized by the drill being collected in the sugar tube when boring, and the tarry product of the fuse when blasting, such oil and tars forming aggregates of the sulphide dust. Regarding the inaccuracy, mentioned by previous speakers, in the method of determining the number of dust particles with the konimeter, he believed, if a person used a petrological microscope for counting, he need have no doubt as to which were water particles and which were dust particles.

(*Discussion continued on* 21*st April*, 1921.)

Mr. A. Fairweather said they were indebted to Mr. Warren for the trouble taken in the preparation of his paper—firstly, because a consideration of that new phase of mining science would help members individually; and secondly, because the interchange of ideas would have beneficial results in the industry. He regretted Mr. Warren did not include a description of all mechanical methods for allaying dust by dealing specially with the rock-drills. As there was a call for less dust, so there was a call for less manual strain and higher mechanical efficiency in machines. They had to combine all their requirements in the one tool. To discuss how all the best features could be combined in the one tool would be most interesting and helpful. Perhaps at a future meeting the subject would be handled in that way. Mr. Warren had referred to the Clifton apparatus, a device originally designed for attachment to a "Long Tom," and to allay the dust when such a machine was used in rising. South mine officers had improved that apparatus, but did not consider it was by any means perfect, and knew better than anyone its limitations. It had been of the greatest service to them in popping work, and had enabled them to convert a large stock of dry-boring hand-rotation poppers into very satisfactory machines. It was tested in a rise by a pair of miners highly prejudiced against rising, and their verdict, on the completion of the job, was that the apparatus made rising a comfortable operation. No difficulty was experienced in boring corner holes. Unfortunately, it could not be fixed to an automatic-rotation machine, and suited best a type of machine that was going out of use—viz., the dry-boring telescopic stoper. They, however, did not know any way of rising that was superior to the use of a "Long Tom" with Clifton device in regard to freedom of dust and lack of discomfort to the miner. In regard to water blasting, it was frequently argued that the practice of it must increase the humidity of the mine air. The argument, however, had never got beyond the stage of an assertion, and it was advisable that tests should be conducted to determine the question scientifically. Admittedly, water blasting caused the dissemination of vast quantities of minute water-bubbles through the air. These attached themselves to dust particles and fell. It was believed that the taking-up of water as water vapour was thus assisted. But the conditions favourable to high humidity were always present in the mine. Wet tailings were used as filling. Water flowed along the drains of every level and through the flaws in the rocks—either ground water or that introduced for use in water jets or axial water-feed machines. A general water-blasting system would be called into requisition only at the end of each shift, or, in isolated cases of firing, at crib-time also. Thus the increased tendency towards evaporation of water (if that really existed) was present only at long intervals. The water drops from a blast took a very short time to settle, and the amount of water used, even supposing a blast were used behind every explosion, was a small part of the total amount introduced for watering holes and piles of ore and that contained in the wet residues. There had been a tendency in the discussion to compare a water-blasting system of dust-suppression against a system of removing dust by ventilation—in other words, to pit the use of water against the use of air currents. No one could urge any argument against copious ventilation, but if that method were relied upon solely for dust removal it was hard to imagine how it could operate successfully on a metalliferous mine where there were numbers of levels, and where so often the supply air to a stope consisted partly of the exhaust air from another stope. Ventilation would move the dust from one place to another; but what was wanted was a method that would cause it to settle in the shortest possible time. The water system achieved that. Copious ventilation should be regarded as an adjunct to water blasting, but not as an alternative. For the past four or five years South Africa had been water-blasting on an extensive scale, and the latest reports from that country covering the results of dust-sampling were most satisfactory. He had read nowhere that any person competent to speak on that matter had condemned the use of water in blasts following explosions. South Africa had pointed out the difficulty of making the blasts effective in large stopes, but the mining men there did not condemn blasting in consequence. They adopted it as extensively as possible. But even if dust-suppression by water-blasting was not completely successful in any one stope they could prevent the exhaust air from the stope causing the vitiation of the supply air to another working place adjacent. That could be done in a manner suggested by Mr. Warren, and which had been proved successful on the South mine. The dust-laden air was water-blasted at all the exits, and the blast was directed with the natural air current in order to assist it. If one might judge by the latest publication of the Chemical, Metallurgical, and Mining Society of South Africa, the authorities in that country were not yet satisfied that everything possible had been done in dust-suppression, and the consensus of opinion was that further improvement must be effected along the lines of increased ventilation. There was no suggestion that water-blasting should be abolished or even curtailed. They should be influenced by the opinions of others who had wrestled with those problems much longer. Thus, he contended, there was no opposition between water-blasting and adequate ventilation as aids to dust-suppression ; they were complementary to one another ; and if there were a danger of increased humidity from increased use of water, then let them hold down that humidity by ventilation. It was far better to employ ventilation for that purpose than to use it for the dilution of dusty air.

Mr. Voss Smith said Mr. Fairweather had referred to the March number of the *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, which published the discussion by members of the society at its meeting held on 19th March, 1921. The general impression one got from a perusal of those discussions, which were by no means finished, was that more attention was to be paid to the dust question than had already been done, although they had gone a tremendous distance. In effect, they summed up the position as follows : that they have got no one thing that was 100 % efficient, and, instead of waiting for that one thing to turn up, they suggested using every means practicable to build up step by step. Water blasts were commented upon a good deal, and the general impression was that they were by no means going to turn them down. Mr. C. J. Gray, Inspector of Mines, Johannesburg, said :—

" Though immense amounts of thought, work, and expenditure have been devoted to prevention of miners' phthisis in the mines of the Witwatersrand, and great progress has been made, the disease is still very serious. As those who do not know the facts are tempted to assume that all that is possible to deal with dust underground has been done, it may serve a useful purpose if I point out some of the respects in which present conditions and measures are open to improvement. . . ."

Again :—

"Recent investigation has shown that the water blast *as used* is a very poor safeguard—even when it is working properly the force of the explosion of the shots will drive fine dust through the spray from the water blast, but in practice the water blasts seldom work properly.

"Individual water blasts will work well when tried during the working shift, but when all in the mine are open at blasting time, and air pipes in winzes, &c., are blowing, there is often insufficient compressed air to supply them all, and they fail hopelessly. Therefore, when the 'lashing shift' goes into development places the approaches to the faces often are not cleared of dust, and at the faces, though the compressed air from the water blast may have cleared away fumes and dust, the broken rock is dry, and dust is raised in watering down.

"To improve matters, I should recommend :—

(*a*) More attention to the settling and filtering of water, so as not only to remove silica particles, but also those deposits which may be formed in the aeration or neutralization of water supplies.

(*b*) More careful neutralization and control over the contents of water, so as to avoid corrosion or incrustation of pipes, &c., and early replacement of corroded or incrusted pipes.

(*c*) Greater care to ensure that main pipes are of ample size, so that they will allow the required flow without undue friction when the use of water is at its maximum.

(*d*) Greater care in the placing and protection of water pipes.

(*e*) Extended use of water (not air) fed machine drills.

(*f*) Greater care in placing sprays and atomizers, so that they will not wet persons unnecessarily.

(*g*) Attention to the drainage of development ends, so that water will not accumulate there.

(*h*) Use of water blasts which are economical in compressed air, and will work with air at low pressure."

Also :—

"Though improvement may be made, I think that when owners and managements have done all possible with regard to the use of water, there will still be frequent failures to prevent formation of dust. The simplicity and constancy of action of a good ventilation system can never be obtained in the use of water, and therefore it is important to back the use of water by ventilation."

South Africa apparently relied too much on the water blast previously, and now felt that they wanted to do a lot more than water-blasting. It struck him forcibly that Dr. Chapman was inclined to let the ventilation question be dealt with as a separate phase of the question altogether, and to deal with dust first and ventilation afterwards. But, on the South African experience, the two things seemed to be interlinked the whole time. In regard to the humidity difficulty, increased ventilation would help a lot to get over that. Then there was a suggestion that a lot of the dust trouble was due to drilling when the water service was not working effectively, and it was asked that drilling should stop as soon as the water supply went wrong. The suggestion was made that machine drills should be provided that would not work without an adequate water supply. In the discussion mentioned above Mr. C. J. Gray said :—

> " Water sprays and atomizers, though not very important directly, being unreliable and inefficient, are sometimes important indirectly, as they enable the air to take up moisture . . . ."

which, he thought, was contrary to what Mr. Fairweather stated. Throughout the South African discussion they linked the water system with the ventilation system for dust purposes as apart from purely ventilation purposes.

Mr. H. F. Pearson said in the course of the paper under discussion Mr. Warren had given the results of dust samples that were taken with the Kotze konimeter under varying conditions. It was on the method of counting those spots that he (the speaker) desired some further information. There were two methods of counting recommended by the South African Miners' Phthisis Prevention Committee, and they were :—

(1) By counting the particles of dust between two lines intersecting at either 9° or 18°, and making the necessary calculation from that result.

(2) By using an eye-piece ruled in squares, ascertaining—
  (*a*) The dimensions of the spot.
  (*b*) The average number of particles per square, and so obtaining the count per cc.

The above committee also recommended a magnification of 150–180 times as giving the best results for counting. He had been using 185 and an eye-piece ruled in squares. Some dust samples which he took recently were check-counted by Mr. Warren, whose counts were all higher. The results were :—

——	Self.	Check.	Percentage of increase.
(*a*)	460	491	6½
(*b*)	383	531	40
(*c*)	491	639	30
(*d*)	289	344	20
(*e*)	542	590	7
(*f*)	1,400	1,431	2

He must apologize for not being able to show the slide containing spots *b*, *c*, and *d*, as the spots had been obliterated on the South mine after check-counting. To show how easy it was to obtain a different result of a dust count, he would relate the history of spot *a*, 460—491—6½ %. The first time that he counted that spot he estimated it at 366 per cc ; the check count said 660. He had another attempt on hearing that, re-estimated it at 460, and sent it along for a further re-check ; it was returned as 491. The method that he had been using for determining the number of dust particles per cc. was, roughly :—

(*a*) Obtain the maximum dimensions of the spot along two axes at 90° to each other, and multiply the product of these two dimensions by 8, giving the area to 2 %. With the knowledge of these two dimensions the centre of the spot could be made to coincide with the centre of the squared eye-piece.

(*b*) Count the particles of dust from one side of spot to the other in the two rows of squares running at right angles to each other through the centre of the squared eyepiece. Average that total over the number of squares counted and multiply the total area in squares by the average figure obtained.

He understood that Mr. Warren's method of counting was similar, except that to average the number of particles per square he counted the particles in a square figure containing 9 grid squares in each quadrant and divided the total number of particles by the number of grid squares containing them. That brought him to the question of the average number of particles per unit area, or in that case per square. Imagine an ideal spot 20 squares in diameter and true area of 314 squares, increasing regularly in density towards the centre, the square on the edge of the spot having one particle, the next square nearer the centre having two particles, then three particles, and so on up to ten particles at the centre square. Then counting by his method would give 220 particles of dust in the two rows, each containing 20 squares—average per square $= \frac{220}{40} = 5.5$. Total particles in spot $=$ $314 \times 5.5 = 1727$ particles. Regarding that spot as a series of concentric rings, the outside ring containing 1 particle per unit area, the next inner ring 2 particles per unit area, and so on up to 10, they found out that the total number of particles in the circle worked out at 1205, or a difference, 43 %. from the previous result, whilst the real average per square was only 3.8 instead of 5.5. The actual dust spot appeared to be far from such a regular object as the ideal one just mentioned, and he should like to ask Mr. Warren the following questions:—(1) Although the method he (the speaker) used for averaging the particles per square was, in an ideal case, mathematically incorrect, did Mr. Warren consider that a dust spot was sufficiently regular in the decrease of particles per unit area from the centre to the perimeter to render the method inaccurate and unreliable? (2) If so, upon what basis did he select the nine representative squares in each quadrant?

(3) If the spot was simply an irregularly-distributed collection of dust particles, which of the two following methods would appear to give the most convincing result:—

(*a*) An average content based on the dimensions of the spot, or

(*b*) An average content based solely on areas selected at the discretion of the operator?

He was inclined to think that in any case his counts would be on the heavy side, as, in averaging, the due proportion of less dense squares around the perimeter were neglected; yet the check counts by Mr. Warren were all higher, varying in some cases from 20 to 40 % in comparatively low counts. Then as regards the dimensions of the spot. The South African Miners' Phthisis Prevention Committee recommended a magnification of 150–180 for counting. Besides giving a clear definition of particles 1 micron in size, that magnification had the advantage that the average dust spot approximated the size of the squared grid, or perhaps 22 x 22 squares. That allowed the operator to see a fairly large portion of the perimeter of the spot without moving the slide, and thus gave a fairly comprehensive idea of the average boundary. With the magnification of 225 that Mr. Warren used, the average-sized spot was 28 or 29 grid squares in diameter. With that magnification (225) the operator could see a smaller portion of the spot at one setting of the slide, and would not get so good an idea of the boundary without much use of the mechanical stage. With that high magnification it would appear a simple matter for individual operators to obtain varying estimates of the dimensions of a given spot, thus making all the difference between a high count and a low one. He had examined some dust spots under a magnification of 250, and could detect no particles that he could not see at 185, but perhaps his eyesight was at fault. Some additional questions he would like to ask were:—(4) Did Mr. Warren not think that, with the higher magnification power, an operator was more liable to over-estimate the size of the spot than with the lower power? (5) What were the particular advantages of that magnification? (6) Were the qualitative grid lines 5 microns apart at that magnification? In conclusion, he would like to ask if the method of counting with a squared grid was sufficiently free from estimate by "judgment," both in averaging the number of particles per square and the dimension of the spot, for an operator to prove to a third party that his count was correct, and that the count of an opposing party was wrong. It seemed so easy for an operator to make a spot go any count within certain limits, and it looked much harder to definitely disprove that count as the question of "fair average" came up. To eliminate most of the estimate by judgment, did Mr. Warren consider that the eye-piece with intersecting grid lines would meet the case? He submitted the drawing of an eye-piece (Fig. 1) upon which he would be pleased with an expression as to its feasibility. Lines XX and X^1X^1 are

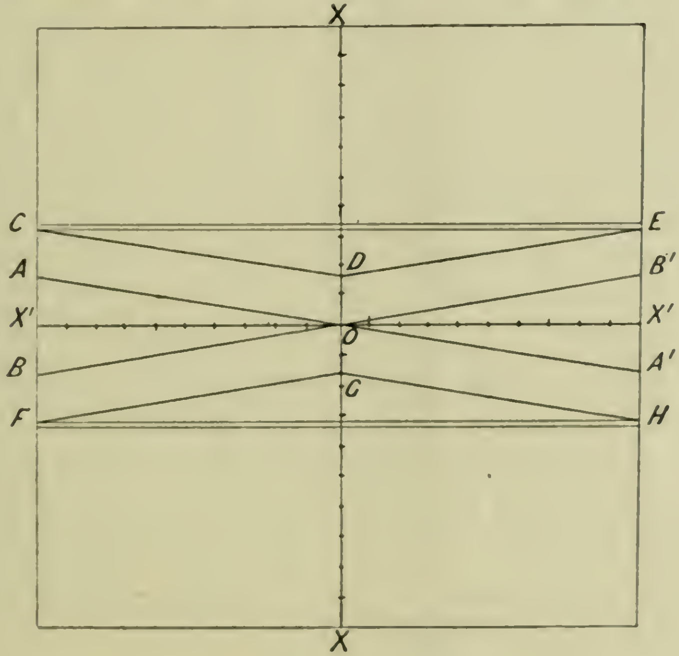


FIG. 1.

bisecting each other at 90°, and are each divided into twentieths. AA^1 and BB^1 are lines intersecting each other at the centre O, and at an angle of 18° to each other. $DG = AB = A^1B^1$, and from D and G lines DC and GH, DE and GF, are drawn parallel to AA^1 and BB^1 respectively. The two lines joining CE and FH are the qualitative grid lines to be 5 microns apart at some given magnification. The method of use was similar to that of the South African Committee, but when the spot extended beyond AB the operator identified some distinctive particle on AB, and moved the slide to the right till that particle had a corresponding relationship to DG. Then the operator counted all the particles in the figure CDGF. Those four extra lines removed the necessity, where the spot extended beyond the confines of the eye-piece, of extending the two lines AA^1 and BB^1 in the magnification. The only estimates required were the two dimensions of the spot for centring purposes, and an error of ± 2 would, he thought, be negligible in the final count with grid compared with computation by squares. However, that was only an opinion, as he had never used the intersecting grid lines.

Mr. T. A. Read said several of the previous speakers expressed doubts as to the konimeter method being reliable, and quoted the gravimetric method as being the more reliable of the two. In the investigations carried out both in South Africa and the Joplin district it was found that it was the fine particles of dust—*i.e.*, particles under 5 microns—that caused serious harm to the miners. It would therefore appear that a method which would give the number of particles of dust present in a given volume of air would give a much clearer conception as to the unhealthiness of air than a method in which the results were expressed by weight. That this had early recognition by the South African people was evidenced in their earlier work, whereby they adopted the method of counting in the hæmacytometer cell portion of their sugar-tube catch. *The Konimeter Method.*—Objections raised against the konimeter method were :—

(1) Errors in counting the dust.
(2) Small quantity of sample taken by instrument.
(3) Pit marks on the vaseline being mistaken for dust spots.

(1) The error in counting may be as high as 10 % when the dust spot contained upwards of 1500 particles per cc.; with dust spots containing a lesser number of particles per cc. the error was much less. That error was not a serious one, for where atmospheres

contained dust approaching that figure it was quite apparent that some means for allaying the dust was necessary, and should be used. In counting the dust on the slide, he found it best to use an eye-piece ruled in squares, and also to have a mechanical stage for quickly locating the dust spots and to traverse the spot for obtaining its correct diameter. (2) That applied equally to the gravimetric method. The konimeter sample was 5 cc. The readiness in which that sample could be taken and counted allowed of a number of samples to be taken from the one face and an average of the counts taken. In the gravimetric method the sugar-tubes were usually placed in one position, supposed to represent the average of the place, and the sample taken; there was no guarantee that an average of the dust-laden air passed the sugar-tubes. (3) That the dust particles caught on the vaseline slide were visible in plane light depended upon the difference in the refractive index of the minerals forming the dust and the mounting medium. The outline of the dust particles (which were crystals) would gradually disappear if the index of refraction of the surrounding liquid gradually approached that of the dust particles, and the dust particles would be invisible if the two indices were alike, provided the dust particle or crystal were colourless. Therefore, the mistaking of pit-marks caused by water globules impinging on the vaseline for dust spots will improbable. What he had found, which at first was a little confusing, was the presence of small globules of water on the slide when testing certain classes of work (fogging of water Leyner, and water blasts). That was got over by allowing the slide to stand about an hour in a dry room, when the water spots would have disappeared, leaving in some cases pitting of the vaseline. The appearance of the vaseline on the slide due to that cause was that of being slightly blurred, owing to the hollows being slightly out of focus. By carefully adjusting the focus over those places there was no sharply-defined outline, as was the case when a dust particle was in the vaseline. In every probability, soft glycerine jelly might be a better medium than vaseline for coating the slide when water globules were likely to be encountered in the air.

The impression that the gravimetric method was much more accurate than the konimeter method was not well founded, when applied to Broken Hill dust. The gravimetric method, largely used by the South African people in their investigations, was quite a simple one. Broadly, the method consisted of collecting the dust sample in sugar tubes, the sugar taken into solution by distilled water, and the insoluble dust separated by filtration; the filter paper was given a wash, and then incinerated and weighed. the weight obtained having due corrections for dust present in the sugar and the ash of the filter. The method, no doubt, had yielded reasonably accurate results to the South African investigations. The same method applied to the dust occurring in the Broken Hill mines would not be accurate, on account of the chemical changes brought about during ignition. In some investigations into the chemical nature of the dust in the Broken Hill mines, carried out by himself, he used the above method, with the following modification:—The suspended dust was filtered off through a weighed Gooch crucible having an asbestos filter, washed six times with distilled water, and the crucible and contents dried at 100° C. and weighed. The suitability of that modified method was determined by taking a Gooch crucible and filtering 1 litre of 4 % sugar solution through it, and then washing six times with distilled water. The crucible was dried at 100° C. and weighed. By repeating the experiment five times, the weighings, with the following differences, were obtained:—

———	Grammes.	Difference from original weight in milligrammes.
Original weight	19.2373	—
1st filtering and weighing ..	19.2375	0.2
2nd ,, ,, ,, ..	19.2378	0.5
3rd ,, ,, ,, ..	19.2378	0.5
4th ,, ,, ,, ..	19.2374	0.1
5th ,, ,, ,, ..	19.2377	0.4

It would therefore be seen that the method modified by weighing in a Gooch crucible showed differences ranging from 0.1 to 0.5 mg.

In the method used by the South African Miners' Phthisis Prevention Committee, although not stated, the chemical balance for weighing the ignited residues or dust would be in all probability the usual chemical balance, with which the closest one could weigh would be ± 0.05 mg. As it was the number of small dust particles that were injurious to the lung, those differences in weight would account for a large number of fine particles. It would therefore be seen that the gravimetric method was subject to errors, and the method, when modified to suit the chemical character of the Broken Hill dust, had errors greater than the konimeter method. For investigation into methods and apparatus for determining the efficiency of same for the suppression of dust, the konimeter method would give the information required. Where a general investigation into dust conditions was being made, in which it was necessary to determine the chemical nature of the dust, as well as the quantity of the dust, both methods should be used, because, by the gravimetric method, a lot of interesting points about the dust could be investigated.

Mr. Warren, in reply, said Mr. Whiteman's explanation of the comparatively inefficient work of blasts "A" and "B" in the developemntal dead-end firing test was probably quite accurate. It would be noticed that the blasts only ran 15 minutes. The compulsory time of running in South Africa for that class of work was 30 minutes. The reason why blast "C" showed such good results was that the strength of that blast caused considerable local ventilation, having the effect of washing the end out. As it was impossible, except in very rare cases, to conduct the noxious-firing products and dust direct to the upcast, that might appear bad practice were it not for the fact that the dust was wetted and must therefore come down much more quickly than if dry. He had repeatedly obtained dust spots in the track of a water blast, which showed individual particles and aggregations of dust surrounded by definitely-marked rings, caused by the spreading of the water on the vaselined slide. A photograph of such a spot was available for inspection. The spot was not a well-shaped one, but showed the feature described. Referring to firing in ventilated stopes, Mr. Whiteman mentioned that he thought the low dust-counts obtained from the blast "C" test might be attributed to the increased speed of the ventilating current and the consequent dilation of the noxious and dust-laden air. That, it was claimed, was the great advantage to be obtained in using water blasts in that way. When pointed in the direction of the ventilating current, they had a most beneficial effect. Experiments had been conducted which proved that the quantity of air flowing into isolated stopes difficult to ventilate was doubled. That was a most desirable achievement, especially in places where the firing products had a tendency to hang owing to sluggishness of the air currents. As the blast filled the gangway for at least 50 ft. ahead, it was very improbable that any dust particles could escape a wetting, and must therefore come down before they had travelled far. In order to throw a little light on that point, the following test was done in the 1270-ft. level, section G, stope mentioned on pages 45 and 47 of the paper. The "C" blast was situated at Z as before, but all samples were obtained at a point round the bend of the gangway, some 80 ft. from the winze.

No.	Conditions.	Total Dust per c.c.	
		1. No water blast.	2. Blast "C" on 10 mins.
1	2 mins. after firing in stope	Too thick to count	3775
2	5 ,, ,, ,, ,,	,, ,, ,,	1840
3	10 ,, ,, ,, ,,	2113	343
4	15 ,, ,, ,, ,,	565	221
5	20 ,, ,, ,, ,,	229	97
6	25 ,, ,, ,, ,,	221	84
7	30 ,, ,, ,, ,,	180	84

The stope was well ventilated, and the holes were fired close to the winze. The water blast in test 2 was stopped at 10 minutes after firing. Attention was directed to samples 1, 2, and 3 in each test. Samples 1 and 2, test 1, were too thick to count, but would, on a rough estimate, contain at least 10 times the quantity in Nos. 1 and 2, test 2. The dust of test 1 would be carried dry to vitiate adjoining stopes on the 1170-ft. level, while a considerable portion of the dust in test 2 had been eliminated before the air reached the sampling point, and the balance, being wetted, would not travel nearly so far as the dry dust before settling. Mr. Clayton stated :—"In the results from firing obtained under working conditions prior to May, 1919, no velocities of air currents are given in the stopes, which might be dead-end, similar in conditions to those of a drive." The counts in question were obtained in the 1070-ft. level, sections F and D, stopes, which at the time were fairly well ventilated, though the air velocities were not recorded. The air had free passage from the 1070-ft. level through chutes and ladderways, along the backs, and up to the 970-ft. level through winzes. The stope temperatures at the time of sampling were 69° to 71° F. It was claimed, therefore, that the stopes were truly representative of Broken Hill, with a through air current. He did not understand the statement that it was difficult to count dust under 3 microns. If that were so, it would not be much use attempting to count dust spots at all. At least 90 % of the dust got from boring and firing was under 3 microns. The degree of magnification used in counting—viz., 225 diameters—enabled them to clearly see particles down to 1 micron. In quoting a report recently issued by the South African Chamber of Mines to the effect that a silica particle 3 microns in size falls through the height of a drive in 33 minutes, Mr. Clayton did not mention that a silica particle 1 micron in size took 5 hours 30 minutes to fall through such a height, and that was given as the reason why dust samples always showed such relatively large quantities of extremely fine particles. No water blasts were used after firing when the stope samples above referred to were obtained. The men would return to bar down and shovel ore—operations which, in themselves, did not produce heavy quantities of dust. The statement that a water blast would stir up dust was correct, but not in large quantities. On the 19th December, 1918, a count obtained in a dead-end crosscut in which no work had been done for some months went 80 particles per cc. immediately after wetting down with the water blast. There was a danger, in obtaining spots after water-blasting, of mistaking water globules for dust particles, but the distinction could be readily made if care were exercised. *The Use of Water Blasts in Stopes.*—Considerable discussion had arisen upon that matter, mostly hostile to the suggestion put forward that every stope face should be supplied with at least one blast. As that was an important matter, he would try and put his reasons for making that suggestion more clearly. The outstanding difficulty in dealing with dust from firing in stopes was that in most Broken Hill mines the dust necessarily traversed a succession of working faces before getting into the upcast shaft. While that did not matter much when firing was confined to the end of the shaft, provided the men were hauled to the surface through a downcast shaft, it was a matter of great importance when firing at crib time, as was necessary on most Broken Hill mines, every shift, in order to keep the truckers busy. The men always had crib near their working-places—sometimes in the stopes—and therefore in the track of the air as it passed to the upcast shaft. It often happened, too, that, even at the end of the shift, men were exposed to the effects of dust-laden air from stopes where the miners had perhaps fired 5 minutes too early. On a recent occasion he obtained a heavy count from the inlet air to a stope at 1 p.m., when no firing had been done at crib time. Inquiry elicited the fact that the dust, which was extremely small (about 1 micron in size), had in all probability come from a stope a considerable distance away, where some holes had been fired 1 hour previously and no water blast had been used. The 970-ft. section *H* stope was chosen for the test quoted in the paper because it was a dead-end stope, the object being to demonstrate the capabilities of water blasts in allaying dust. It was therefore desirable to eliminate the factor of ventilation. Fortunately, stopes of that sort were rare, the practice being to sink winzes in advance of the sill-floor stoping. Mr. Clayton pointed to the difference in size of the Broken Hill huge stoping areas and those of South Africa, but he (Mr. Warren) thought the differences were such as to favour the use of water blasts in quite a large proportion of the stopes. The square-set method of mining was extensively used, and would be still more availed of in future. The area open in a square-set stope was, as a rule, relatively small compared to the ore-body, and the face would be quite easily covered by a water blast. The average open stope and sill-floor stope face in the Broken Hill South was from 30 ft. to 50 ft. in length. While it was admitted that it was not so easy to cover faces so long, the "C" blast described in the paper would carry 50 ft. comfortably; and, arranged parallel to the face so that the dust had to pass through a curtain before reaching the outlet, it was claimed that some good service in dust-allaying was achieved in that manner. The popping was not, as suggested by one or two members, some distance behind the face. As a rule, in mines where the miners were set fortnightly contracts, it was very close to the face. It was not essential, however, that the water blast be placed close to the face, so long as it intercepted the dust between the face and the winze. Rather contrary to expectations, the water blasts have cost little for repairs and maintenance, while the matter of keeping them moving with the faces did not occasion any additional expense, as the air and water pipes must be moved up in any case. There was another use for water blasts in stopes which had not been mentioned—that was, to assist in keeping accidental dust in check. It was no uncommon sight to see a cloud of dust resulting from every movement in a hot square-set stope, the heated air having absorbed the moisture from the filling. A water blast in such a place was much more effective than a jet in damping the surfaces down. They also often found the miners using the blast to wet a pile of ore before filling. Dealing now with the question of cost of water blasts, he thought that Mr. Hanton's estimate of 4s. per hour was rather low. It was practically impossible to estimate the cost of compressed air delivered underground; in any case, such costs would vary greatly on different mines, but he estimated the cost of running the "C" blast at 1d. per minute. At first sight the cost might appear somewhat alarming, but it must be conceded that, in order to control conditions affecting health, some money must be spent. The amount of compressed air used by a water-blast system properly organized could be to some extent controlled, whereas the old method of blowing out places with the air hose was very wasteful of air, besides having the effect of stirring up large quantities of dust. On the South mine the men started the blasts when they fired, and after they had run for the fixed length of time for the level the bosses turned off the valves in the mains. The local problem of dust-allaying differed from that of Johannesburg in an important respect. Whereas Broken Hill dust from sulphide ore-bodies contained only about 50 % of insoluble—silica and silicates—against 95 % in South Africa, it also contained sulphide of lead, which might have an important bearing on the incidence of lead-poisoning. *The Clifton Dust Collector.*—He regretted that Mr. Hanton should have lost his admiration for the Clifton rising apparatus as a result of his experiences with it. However, he did not think it could be said that the apparatus, in its present form, had yet been tried out sufficiently under working conditions. The original apparatus made by Clifton was given to a party of rise miners on the Broken Hill South mine, who used it to carry up an inclined rise for a distance of some 30 or 40 ft. The miners used the apparatus right through, and spoke of it in a respectful manner. That fact, of course, influenced them in trying to further develop the apparatus. All the local mines were represented at the various tests of the apparatus held at the South and Junction mines, and it was finally approved in its present form by the Underground Managers' Sub-committee of the Mine Managers' Association. However, as Mr. Hanton's criticism was based upon personal experience, it must be treated with respect. (1) Bad joint with back.—It was early realized that the apparatus could not be efficient unless a good joint were made in order to prevent leakage of both dust and water. The sponges used were simply toilet sponges split and sewn round the top of the dish. The experimental results were good. No doubt better efficiency in that respect could be obtained by using a soft cellular rubber ring designed for the job. (2.) It was admitted that the apparatus was likely to prove a little inconvenient for side and corner holes, especially in a rise only 6 ft. x 4 ft. Some relief from that difficulty could be had by setting the machine in from the side of the rise and allowing the holes to lock back some 4 to 6 in. in a cut. (3.) As Mr. Hanton said, "Under the best of conditions it was difficult to collar a hole exactly where desired." They could not have everything exactly as they would like it. (4.) Lack of space in a rise, to be dealt with later. (5.) The iron or steel threads of any machine in a mine must be kept well oiled, to prevent rusting. (6.) Wearing of rubber sleeve and sponges.—The efficiency of the apparatus did depend on those parts to a considerable extent. Fortunately, they were easily replaced at low cost. It was understood that the supervision should be sufficiently good to relieve the miner of the responsibility of deciding when those parts should be replaced. (7.) Water running out from dish when changing steels.—It should not be hard to overcome that inconvenience. (8.) Water played only round the collar of the hole, it was true. It was also true that the outside jet gave very little better efficiency when used on rise holes. It often happened that miners, sooner than be bothered with the jet in rises, would bore dry. (9.) As stated above, the original Clifton collector was tried out in an inclined rise. Bound up with the discussion of the merits of that apparatus was the whole question of rising. Local miners had a violent antipathy to working in rises, and, in his opinion, justifiably so. As rises could not be entirely done without, it was wise to make the conditions of work in such places as attractive as possible. That could only be done by increasing the size to provide for two compartments, giving the men ample stage accommodation, room to work in comfort, and adequate ventilation. Axial water-feed machines, while dealing with the dust, were wet to work under, and it was hoped that the Clifton dust collector, which was the best apparatus of its sort yet devised, and which, doubtless, was capable of further improvement, would serve to make rising a more acceptable occupation for miners. The popper Clifton dust collector was, of course, of far more importance to managers because of its vastly greater field of use. It was at present used by every ore-breaking party on the South mine, and was very popular with the miners. In answer to queries, he could say definitely that it had rendered popping a one-man operation on that mine. The introduction of axial water-feed poppers with automatic rotation would render the popper Clifton unnecessary, but it should be remembered that such machines were heavier, cost more to run, and were more likely to get out of order than hand-rotated poppers of the Waugh 22P type. *Humidity of Mine Air After Using Water Blasts.*—The use of water blasts after firing in working places always resulted in the air in such places becoming temporarily saturated with moisture, accompanied by a slight drop in temperature, due both to the cooling effect of absorption of moisture and the adiabatic expansion of compressed air. The South African Chamber of Mines, in a recent statement, said :—

"It is important that all rock surfaces throughout the mine should be kept damp, and this can only be accomplished if the air is saturated with moisture, or nearly so. No practical amount of hosing and watering of drives, stopes, &c., can be effective in the presence of a current of dry air. As a rule the simplest means of conveying moisture to the air is to keep the downcast shafts thoroughly wet, and to instal sprays at suitable points in the main in-take air-ways."

However desirable it may be from a dust-allaying point of view to fill the mine with saturated air, they all knew that such air was undesirable from a physiological point of view, unless it had either a low temperature or considerable velocity. Good ventilation could only be obtained by the provision of an adequate supply of air directed through the working-places. When such conditions of ventilation existed, as they should, in order to secure efficient working results, he did not think that the humidity caused by water blasts need occasion any great concern in a well-ventilated mine, for the following reasons :—(1.) Water blasts did not run during all the shift, but for 15 minutes or so at firing time. If sufficient attention had been paid to ventilation, the air, which was claimed to be completely saturated, was readily removed from the mine. (2.) The condition of the air—*i.e.*, saturated or otherwise—in a mine depended upon the quantity of moisture in the country rock and wet filling, and the addition of any water supplied by means of a water blast was practically not worth considering. (3.) If water blasts which were used for only 15 minutes in a shift were going to upset the average conditions in a working face, it would seem advisable to refrain from using water in drilling operations, which were conducted for practically the whole shift. The average relative humidity of a set of readings taken recently in 20 stopes was 87.5 %. The readings were obtained between 1 and 2.30 p.m. The average for those places in which water blasts had been used at the crib time firing —viz., 50 %—was 86.85 % relative humidity.

Mr. W. D. Whiteman said that, after reading Mr. Warren's paper, he took it that the author indicated that there should be at least one blast in every stope, irrespective of the air passing through it. He (the speaker) was not altogether in favour of the use of those blasts except in developmental or dead-end places, or any places where there was not sufficient air current to remove the fumes and dust. In regard to the velocity caused by the blast, his point in that respect was rather more in connection with the correlation of the tests. He was trying to see what the actual extraction of the dust in that air was, after passing through the blast. He would suggest taking the sample immediately after it came from the winze before passing through the blast, and then, say, half a minute later at the sampling-point, and noting the extraction, in order to arrive at a comparative result with the non-blast test. That was the point he stressed in the first instance. In regard to the fume from the explosion, he thought it was just as important to get that out, from the point of view of comfort to the men, as it was to get the dust out. Another point was in regard to the occurrence of lead dust. He believed that lead particles would fall quicker than dust particles, owing to their greater specific gravity, and a man would not be liable to inhale as great a number of lead particles. In regard to relative humidities with and without the use of water blasts, it appeared to him that water, when it was reduced to a very fine state of division, would lend itself much more readily to absorption and be taken up by the air, than it would trickling down the side of the drives or in the form of water from boring. He had not tried to work out what volume of water it would take to saturate a given quantity of air, but he did not think it took a large quantity over and above normal moisture carried to fill to saturation a space such as a stope.

Mr. Warren supplied the following figures:—Temperature of upcast air, 79.76 after saturating; fan capacity, 145,000 cub. ft. per min. Assuming the fan to work 8 a.m. Monday to 10 p.m. Friday, the moisture removed during that period would be 550 tons. Assuming that the men would require 60 blasts, averaging running time of 15 minutes per day each, that will mean that 41 tons of water are used in those water blasts during that period, which amounts to about 7 % of the whole quantity of water handled through the fan.

Mr. Whiteman, continuing, in regard to the Clifton apparatus, asked Mr. Warren if he knew of any apparatus in use on reciprocating machines in South Africa, invented by Swift.

Mr. Warren said he had seen one, but had seen no results.

Mr. Whiteman said, in regard to the character of the dust, it had been mentioned that the Broken Hill dust was about 50 % insoluble, compared with South Africa 95 %. It would be interesting to note that point in developments in South Africa with regard to the insoluble contents where the percentages varied from 60 to 95 from the East Rand to the other end, and ascertain whether the incidence of phthisis was less marked on the East Rand.

Mr. T. G. Hanton said, regarding the aid to ventilation which it was claimed blast "C" afforded in isolated stopes, he presumed that the quantity of air flowing into the stope would be doubled only for the period while the blast was working. Thus, whilst the men in the stope would derive some benefit, the improvement would be temporary only. He could not quite reconcile the advantages claimed for that blast. If, on account of its high air-consumption, its strength was such that the end was washed out, would not that have a retarding effect on the settlement of the very fine dust particles? It would seem that, in all cases, any ventilating effect obtained from the use of a water blast was only temporary and purely local. Test 1 showed, with no water blast, 180 particles per cc. 30 minutes after firing; test 2, with blast "C" on for 10 minutes, showed 84 particles per cc.—both well under the South African standard of 300 per cc. As men did not return to their working-places within 30 minutes of firing, it would seem from those tests that the use of a water blast was unnecessary. Blasting operations were confined to two periods of the shift—crib time and knock-off. Their experience of the men's crib time habits was that they never had crib in the stopes, that the crib place in the level was invariably free from fumes and dust, and was most unlikely to be in any place traversed by dust-laden air in its passage to the upcast. It appeared, then, that if blasting were restricted, as at present, to those definite periods of the shift, ventilation alone could deal with the removal of the dust. Regarding the use of a water blast in stopes, Mr. Warren claimed that "at least some good service in dust-allaying was achieved in that manner." Would it be sufficiently great to warrant the installation of blasts in stopes? Would not an equally good effect be obtained from a blast at the stope outlet only? Concerning popping operations, he might state that on the Zinc Corporation those were almost invariably some considerable distance—up to 100 ft.—behind the face. The mine was worked on the fathomage system, which accounted for the above. If popping were close to the face, one worry on that mine would be eliminated. Regarding the duration of contracts, for some years past—he thought since the award of Mr. Justice Higgins, in 1916—the members of the local Miners' Union had been instructed not to accept contracts for a longer period than a fortnight. Since then fortnightly contracts had been the rule on all the local mines. With reference to the installation and maintenance of water blasts, their experience on the Zinc Corporation mine had been limited to such a short period, comparatively, that they could say little on the question of costs. Concerning the use of the Clifton apparatus in rises, he feared that Mr. Warren and he would simply have to continue to differ, except in that they both agreed that the apparatus was capable of improvement. He happened to be present at the test of the Clifton in its present form at the South mine. It was only a closer acquaintance, under working conditions, that impressed upon him the disabilities he mentioned previously. Mr. Fairweather stated that the industry was undoubtedly faced with increased costs, but was likewise confident that it would survive that condition. He agreed with him that the introduction of improved machinery, particularly rock-drilling machinery, would be one of the most important factors in ultimately reducing costs. Although the Clifton may be an excellent device for using up the present stock of poppers, was not that to be regarded as a temporary measure only, and would not the real remedy, as suggested by Mr. Fairweather, be in the introduction of machines which would be efficient in dust-allaying capacity and boring speed. He would like to digress slightly from the dust question to say that, as far as drill steel was concerned, the results obtained from internal water feed were very much superior to those of the external jet. As far as rising was concerned, at the time of cessation of rising work, due to the decision of the local Miners' Union, six rises were in progress on the Zinc Corporation, and that class of work was eagerly sought after. Rising was an essential feature of mining operations. Provided equal precautions were taken, why should rising be any more injurious than winzing? They had seldom found miners in rises boring dry. However, if a rise miner would not use a simple jet, he could hardly be expected to be bothered with the more troublesome Clifton. Regarding the size of rises, 6 ft. x 4 ft. had been found ample for requirements on the Zinc Corporation. All rises there, exceeding 15 ft. in height, were carried up in two compartments. That had been the practice for many years. As regards size, the trouble on the Zinc Corporation had been to see that the rise did not fall below the contract size of 6 ft. x 4 ft., as the men would adopt any device, even to cutting the standard timber provided, to prove that they could work in a still smaller space. With reference to the Clifton apparatus for popping as compared with axial water-feed machines of the self-rotating type, he might mention that, for the Zinc Corporation ore, the boring speed of the self-rotated machine was considerably greater than that of hand-rotated machines of the Waugh 22P type. Their experience had been that the self-rotated machines were easier to keep in order than the 22P. The difference in weight was not very great—40 to 42 lb. for the self-rotating type, as compared with 33 to 33½ lb. for the 22P. Since the introduction of self-rotated machines their miners practically refused to use the Waugh 22P. He was informed also that the Denver Rock Drill Co. was taking the Waugh 22P off the market in favour of a machine with automatic rotation. Regarding moisture in mine air, and the passage from the South African Chamber of Mines that Mr. Warren had quoted, the paragraph in question concluded :—"At present the phenomenon cannot be relied upon, but further knowledge may enable us to make use of it." However, he fancied no one questioned the efficacy of moisture for dust-allaying, but dust was only one consideration in underground work, and excess zeal in dust-allaying might give rise to a new set of conditions physiologically worse than the old. As regards square-set stopes, there were very few on the Zinc Corporation, mainly those in which the bridge of ore under a level was removed. He did not think any extension of the system was contemplated. In connection with the removal of saturated air from the mine, which Mr. Warren claimed was quickly effected if sufficient attention had been paid to ventilation, then, provided that firing was regulated, would not ventilation remove dust-laden air with equal facility? If a water blast used 2 gallons of water per minute, or 30 gallons in a 15-minute run, and, say, 20 atomizers were working, it would seem that the addition of that 600 gal. of atomized water to the mine air must increase the humidity to some extent. The question of drilling water was entirely different from that of the water from water blasts. Drilling water was not finely atomized, and was not projected into the air-current. Mr. Warren had pointed out that it was not a question of ventilation *versus* water blasts, but rather of ventilation aided by water blasts. Mr. Warren was fully alive to the benefits of ventilation, as he had made it clear that he considered ventilation essential. He (Mr. Hanton) had, however, endeavoured to point out that danger might arise if ventilation, or the physiological benefits derived from good ventilation, were retarded by the indiscriminate use of water blasts.

Mr. C. H. J. Clayton said Mr. Warren, in his reply, stated that it was easy to count dust down to 1 micron in size. So it was, but it was difficult to get agreement upon the number of particles per cc., and extremely difficult to determine whether it was water-pitting one was counting when the size was under 3 microns. They might easily differ by as much as 100 %, and the difference between 300 particles and 600 particles was that between good and only fair conditions. As stated, 1 micron took 5 hours 30 minutes to settle through the height of a drive, it was so free from weight; and on the contrary it also rose with ease, the point being that dust settled in the stopes was stirred up with every subsequent firing when the water blasts had gone forward with the stope. It was better to get such dust right out of the mine altogether. The dust and ventilation problems were inseparable, and must go hand in hand. Any action taken in the laying of dust must of necessity be looked at from the ventilation aspect, if it was the better preservation of health they were striving for. Were these tiny particles as dangerous in Broken Hill as they had been proved in South Africa, where fibrosis had to be prevented? Were they not going to a lot of trouble and expense to combat an evil which existing figures pointed out as harmless, and becoming more so every year as their ore-bodies contained less and less silica with the increase in the depth of working.

Of 90 men examined by the Commission and adjudged to be suffering from the first stage of pneumoconiosis, between and including the ages of—

29	and	37	there are	12	men.
38	,,	45	,,	23	,,
46	,,	50	,,	15	,,
51	,,	55	,,	15	,,
56	,,	60	,,	14	,,
63	,,	65	,,	8	,,
67	,,	68	,,	3	,,

Of these men, 34, judging from their histories, had in all probability contracted the disease in Broken Hill, while the remainder had worked underground a sufficient length of time to have contracted the disease in the following localities (known to be fibrotic producers) :—

Sewer and railway tunnels	5
Quarries	1
Western Australian mines	12
Victorian mines	14
Tasmanian, New Zealand, and New South Wales gold mines (1 each)	3
Ore-picking, South Australia	5
Copper smelting	3
Queensland mines	4
English mines	2
South Australian mines	5
Never underground	2

Of 44 men examined and adjudged to be suffering from peunoconiosis, stage 2, by the Technical Commission, the ages were :—

33 years	1	man.
35 years	1	,,
Between and including the ages of 37 to 45 years ..	15	men.
,, ,, ,, 46 ,, 50	11	,,
,, ,, ,, 51 ,, 55	6	,,
,, ,, ,, 56 ,, 60 , ..	6	,,
,, ,, ,, 63 ,, 66 ,, ..	4	,,

Of these men, 8, judging from their histories, had in all probability contracted the disease in Broken Hill, while the remainder had worked underground a sufficient length of time in the following localities to have contracted the complaint :—

Sewers and railway tunnels	4
Victorian mines	18
Tasmanian mines	1
Ore-picking, South Australia	3
English mines	2
Western Australian mines	4
South Australian mines	2
South African mines	2

Of 59 men examined and adjudged to be suffering from pneumoconiosis complicated with tuberculosis (or should it be tuberculosis complicated with pneumoconiosis ?) by the Technical Commission, the ages were :—

34 years	1
36 ,,	1
37 to 45 years	23
46 ,, 50 ,,	15
51 ,, 55 ,,	7
56 ,, 60 ,,	7
64 years	1
65 ,,	2
69 ,,	1
70 ,,	1

Of those men, 16, judging from their histories, had in all probability contracted the disease in Broken Hill, and of that 16 two had never been underground, while the remainder had worked underground a sufficient length of time in the following localities to have contracted the complaint :—

Sewers and railway tunnels	4
Western Australian mines	9
Victorian mines	18
Tasmanian mines	1

Ore-picking, South Australia	1
South Australian mines	3
Lead smelter, South Australia	1
South Africa	1
English mines	1
Queensland mines	2
New South Wales gold mines	2

He would not deal with the figures relating to pulmonary T.B. only, nor doubtful pulmonary T.B., as the incidence of dust had very little bearing on the complaint, as far as his knowledge went. In his opinion, the above figures sufficiently showed that the cry for suppression of the small (under 5 micron) particle of siliceous dust was not justified by facts, and they at Broken Hill had still to discover the size of the particle producing the complaints arising from the mining of their zinc-lead ore-bodies. With regard to the statement that their huge stoping-areas favoured the use of the water blast in stopes, the factor of ventilation played the most prominent part, followed secondly by the difficulty of covering effectively a large instead of a limited area. With rising temperatures in their large stopes, they had to depend upon the low humidity content of the ventilating current to effectively cool the body. They could not get velocity of current in the wide areas, and so cool down the body by radiation and convection, but must depend to a large extent upon evaporation. Secondly, a water blast was a forlorn object in a huge open stope 100 ft. wide by anything from 8 to 16 ft. high. With regard to its use in square-set stoping, the impossibility of legislating fairly for all cases was apparent, for, whereas the North mine had 50 % of square-set stopes, the Proprietary 90 %, the South 30 %, the Zinc Corporation had not, up to date, 5 % of such stopes. With regard to popping being some distance behind the face, his previous statement was, of course, correct, as in their case they had been stoping with the fathomage system ; and if the water blast only had to intercept the dust anywhere in the stope before it got to the winze, why not after it had passed through the winze ? Why introduce more gear into a movable place exposed to blasting, like a stope, when, if they were necessary, the water blasts could be permanently located outside? During the last fortnight they had built two bulks at the entrance to a drive to protect the water blast, and had blown them both down with the cut holes, the face being correctly bored out on each occasion. They had blown 3 water blasts to pieces. In a winze they had blown one water blast to pieces, and given the men 2 hours' solid baling to remove the water when they came on shift at 4 p.m. The water-pressure varied throughout the mine over wide limits. When you took water down a winze 90 ft. deep you increased the pressure 39 lb. to the sq. in.—vice-versa up in a stope—and to remedy the difference in pressure cost a lot of money. They found the installation of water blasts in stopes during the month of December, 1920, a most expensive matter, and practically ineffective. Dealing with the question of humidity and its effect, Mr. Warren said:—(1.) "It would be removed by efficient ventilation." So would the dust if it was not damped down ready to be stirred up again. It was his (Mr. Clayton's) contention that dust should be carried right out of the mine by ventilating currents. (2.) "The water blast did not practically saturate." The water blast atomized the water, and if readings of wet and dry bulb were taken before and after using the water blast there would be a considerable increase in humidity. (3.) "Refraining from using drilling water if water blasts were going to add to the humidity." The circumstances were quite different. Drilling water was not atomized, and the water was not introduced into the atmosphere. Water-blast water was atomized, and was brought into intimate contact with a large quantity of air. Surely Mr. Warren was not contending that water blasts did not increase the humidity of the air. He must again thank Mr. Warren for his paper. If the discussion following upon the reading of a paper was the measure of its success and practical utility, he should be gratified.

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By HERBERT LAVERS, A.S.A.S.M. (Member).

PART I.

NOTES ON TUNGSTEN.

INTRODUCTION.

TUNGSTEN occupies an outstanding position amongst metals to-day, for by its use modern manufacturing methods have received a wonderful impetus.

The important part played by tungsten in the recent war is not generally recognized. It was tungsten steel, in the shape of high-speed tools, that kept our soldiers supplied with munitions of war at more than one critical period. Tungsten added the necessary hardness and durability to various metals which were indispensable for carrying the war to a successful conclusion. In the words of Colin

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[This paper is separately bound, and may be, if so desired, detached complete from this number.]

Fink, a notable American metallurgist, "It may some day be said that tungsten made democracy possible." Now that peace has been achieved, popular interest has been increased in the metal, due to improved methods of preparation and the increased scope of its application.

From being classified amongst the rare elements some twenty years ago, tungsten has leapt into prominence amongst industrial metals, and bids fair to increase its importance in the metallurgical world. It has largely received this prominence through its use in the steel industry, and at a later period as a filament for incandescent electric lamps. With an efficiency of over five times that of the carbon filament, which it has largely displaced. it has added greatly to the convenience, comfort, and welfare of man generally. Automobile ignition equipments have accounted for the use of a considerable amount of tungsten for "contact points," likewise a large number of non-ferrous alloys.

There are several factors which indicate a growing consumption of this metal, amongst which may be mentioned :—

(1) The purity of the metal which is now obtainable.

(2) The properties peculiar to the metal which are in great demand by the chemical and electro-chemical markets, and

(3) The new uses which are continually being developed by research.

OCCURRENCE.

The name "tungsten" is of Swedish origin, meaning "heavy stone." It was originally applied to calcium tungstate (scheelite), on account of its high specific gravity. Tungsten does not occur native. The discovery of tungsten is credited to the Swedish chemist Scheele in 1781, but it was considered a rare element until about 1850, when some steel alloys were made. However, it was not until Hadfield, in 1903, reported the results of extensive tests of tungsten steel that the industry developed to any extent.

ORES OF TUNGSTEN.

In some types of ore-deposits tungsten minerals are of frequent occurrence, but in the aggregate the amount of metal present is small. It is combined with other elements in eleven minerals, the principal of which are wolframite (FeMn) WO_4, and scheelite, $CaWO_4$. Both these minerals have been found in the Broken Hill lode, but only in small quantities concentrated in a small area. For the purposes of this paper the writer proposes to deal more particularly with scheelite. This mineral crystallizes in the tetragonal system, crystals usually octahedral in form. It also occurs reniform with columnar structure and massive, or granular. It has a hardness of 4.5 to 5, and is remarkable amongst non-metallic minerals for its high specific gravity—5.9–6. Lustre vitreous, inclining to adamantine. Colour white, yellowish-white, pale yellow, brownish, greenish, reddish, sometimes almost orange-yellow. Streak white; translucent, transparent; fracture uneven. Brittle.

Composition, $CaWO_4$—tungsten trioxide, 80.6, lime 19.4 = 100.

Wolframite.—(FeMn) WO_4.

The wolframite series comprise:—

Wolframite (80 % to 20 % $FeWO_4$, 20 % to 80 % $MnWO_4$).

Ferberite (80 % to 100 % $FeWO_4$, 20 % to 0 % $MnWO_4$).

Hubnerite (20 % to 0 % $FeWO_4$, 80 % to 100 % $MnWO_4$).

The wolframites have been shown to form a complete series with an infinite number of members, from $FeWO_4$ to $MnWO_4$.

Wolframite.—Monoclinic, crystals commonly tabular, also prismatic. Often in bladed crystals; also irregular lamellar: coarse, divergent, columnar, massive, granular. Cleavage, very perfect; fracture uneven. Brittle. Hardness, 5–5.5. Specific gravity, 7.2–7.5. Lustre sub-metallic resinous. Colour dark greyish or brownish-black, brownish-red, streak nearly black or dark reddish-brown. Opaque. Sometimes weakly magnetic.

Ferberite.—Monoclinic, massive, granular, cleavage perfect. Hardness, 4–4.5. Specific gravity, 6.8–7.1. Colour black. Streak, brownish-black to blackish-brown.

Hubnerite.—Monoclinic, crystals usually in bladed forms. Colour, brownish-red to nearly black. Streak, yellowish-brown. Gives a strong reaction for manganese. Specific gravity, 7.2–7.5.

CHEMISTRY.

PHYSICAL CHARACTERISTICS.

The atomic weight of tungsten is 183.6, the chemical symbol W. It is ordinarily obtained as a powder, or semi-fused, crystalline, brittle metal, harder than glass, and having a specific gravity of between 16 and 17. The properties of pure ductile tungsten are entirely different from those of the powdered or cast metal. The hardness varies from 4.5 to 8 (razor steel is about 6). The density of pure wrought tungsten ranges from 19.3 to 21.4. For comparison, aluminium has a density of 2.7, lead 11.4, and gold 19.3. The melting point is 3177° C., and is higher than any other metal. Tungsten becomes more malleable after being heated and hammered, and increases in ductile strength. Under suitable treatment it can be drawn into wires having a diameter of only 0.0004 in., or about one-fifth the average diameter of a human hair.

REACTIONS WITH ACIDS.

Tungsten is unaffected by air or oxygen at ordinary temperature, but at red heat it burns with incandescence in air or oxygen. Sulphuric acid, boiling dilute, has no effect on it. Sulphuric acid, boiling, concentrated, attacks very slowly. Hydrochloric acid, boiling, concentrated, attacks slowly, but neither strong nor dilute affect it at ordinary temperatures. Hydrofluoric, concentrated or dilute, has no effect. Nitric acid, concentrated or dilute, has no effect. A mixture of concentrated nitric acid and hydrofluoric attacks rapidly.

Minerals containing tungsten may be opened out with fusion, with alkalies or alkaline carbonates, or by solution in mixtures of acids.

QUALITATIVE DETECTION.

In the case of minerals, the finely-divided powder is boiled with concentrated hydrochloric acid until insoluble yellow tungstic acid is formed. Metallic zinc or tin is added to the solution, and if the tungsten is present in appreciable quantities a blue colour is formed. (Tin is preferable to zinc, as the reducing action is slower; the zinc may quickly reduce the tungsten to the brown WO_2, and the intermediate blue colour may pass unnoticed.) Columbium and vanadium give a similar blue colour, and molybdenum and titanium give a violet colour, so that if tungsten is present in only small quantities these should be removed by the following procedure:—The alkali extract in water is filtered, the solution acidified with dilute HCl and boiled. The precipitate formed may contain Sb, Mo, Nb, SiO_2, Ta, Sn, and W. This is filtered, and the moist residue treated with a solution of yellow $(NH_4)_2S$. Sb, Sn, Mo, and W pass into the filtrate ; Nb and Ta remain on the filter. The ammoniacal sulphide extract is acidified with HCl and boiled. The precipitate is filtered and washed with a little HCl and HNO_3. Sb, Mo, and Sn pass into the filtrate, whilst W and S remain on the filter. W is confirmed as follows, portion of the residue being taken in each case :—

(1) The residue is suspended in dilute HCl, and a piece of Sn placed in the solution and warmed. In the presence of tungsten a blue-coloured solution is formed.

(2) A portion of the precipitate is warmed with NH_4HO and the extract absorbed with strips of filter paper. These strips are treated thus :—

(*a*) A strip of this paper is moistened with dilute HCl and warmed. In the presence of tungsten it gives a yellow coloration.

(*b*) A second strip is moistened with $SnCl_2$, and if tungsten be present gives a blue coloration.

(*c*) A third strip, dipped in cold ammonium sulphide, remains unchanged until warmed, when the paper turns bluish-green in the presence of tungsten.

COMPOUNDS OF TUNGSTEN.

Tungsten is known to form a number of oxides, the separate existence of which is not definitely settled. The only oxides which are definitely known are WO_2, W_2O_3, and WO_3.

Tungsten Dioxide.—WO_2 may be prepared by the reduction of the trioxide or an alkaline meta tungstate with zinc and HCl. Prepared in the wet way, WO_2 is a copper-red colour ; prepared in the dry way it is a brown powder.

Blue Tungstic Oxide, W_2O_3, is formed when WO_3 is reduced with hydrogen at 250°-300°. It is readily oxidized to WO_3. The hydroxide $W_5O_{14}H_2O$, a dark blue powder with a purple lustre, is formed when tungstic acid is reduced with $SnCl_2$ and HCl.

Tungsten Trioxide, WO_3.—This occurs naturally as tungstite, also in the form of tungstates in wolfram and scheelite. It may be prepared by calcining in contact with air, the lower oxides, the metal, a sulphide, or its hydrate (tungstic acid). WO_3 is the most important compound of tungsten. It is canary yellow in colour at ordinary temperatures, and orange-coloured when heated. A greenish tint is an evidence of impurity, due often to the presence of salts of sodium.

It is fusible with difficulty, and insoluble in H_2O. HCl, HNO_3, and aqua regia, but soluble in HF, KOH, K_2CO_3, NH_4OH $(NH_4)_2$, CO_3, and $(NH_4)_2S$.

Tungstic Acid, H_2WO_4, may be obtained by precipitating a solution of a tungstate with excess of hot acid. If cold acid is used the white hydrate H_2WO_4, H_2O is formed, from which the acid may be obtained by boiling. It is insoluble in HNO_3, and very slightly soluble in HCl. Soluble to greater extent in HF, and readily soluble in solutions of caustic alkalies. Tungstic acid may be obtained from tungsten minerals by heating the fine powder with concentrated solutions of the caustic alkalies and then separating the tungstic acid by fractional precipitation with acid.

Colloidal Tungstic Acid.—Colloidal tungstic acid may be prepared by adding HCl to neutralize the soda in a 5 % solution of Na_2WO_4 and dialysing. The solution may be evaporated to a jelly and heated to 200° C. without losing its solubility. At a red heat it is converted into the trioxide. Solutions containing colloidal tungstic acid are not coagulated by adding salts or acids when boiling. It probably has the formula of meta-tungstic acid—$H_2W_4O_{13}$, $_7H_2O$. The precipitation of tungstic acid from solutions of alkaline tungstates islikely to be incomplete because of (1) colloidal tungstic acid, (2) silico, phospho, arseno, tungstates, etc., (3) meta-tungstic acid ($H_2W_4O_{13}$, $_7H_2O$).

Complex tungstates with phosphates, arsenates, borates, silicates, etc., are very numerous. These complex tungstates are stable in neutral and acid solutions, but alkalies resolve them into their constituent salts.

Potassium tungstate, K_2WO_4, is a white salt fusible at a red heat; and then capable of taking up more WO_3. It becomes more fusible as it takes up more $WO\frac{1}{3}$. It is soluble in its own weight of cold H_2O, and has a strong alkaline reaction.

Sodium tungstate, Na_2WO_4, is a white salt like the potash one. *Ammonium tungstate* probably exists in solution when tungstic acid is dissolved in ammonia. *Ammonium paratungstate*, $5(NH_4)O_2$, $12WO_3$, $_{11}H_2O$, is only slightly soluble in water. All the ammoniacal tungstates leave tungstic oxide on ignition in air. With the exception of $MgWO_4$, the tungstates and paratungstates of the other metals are insoluble in water and dilute acids. Strong acids decompose them with the formation of tungstic acid. Organic acids do not effect this change.

Mercurous tungstate, Hg_2WO_4, is easy to work with and convenient for separating tungstic acid from solutions. It leaves the oxide WO_3 on ignition.

Silico-tungstic acid, $_4H_2O$, SiO_2, $12WO_3$, is very soluble in water. It may be evaporated and dried at a temperature of 350° C. without losing its solubility; at higher temperatures it is decomposed into SiO_2 and WO_3. *Mercurous silico-tungstate* is insoluble.

METALLURGY.

Tungsten, despite its high melting-point (3177° C.), readily alloys with steel, and ferro-tungsten assimilates yet more readily with molten steel; 90 % of the tungsten extracted from its ores goes into high tungsten alloys with iron.

Tungsten steel is used for the manufacture of self-hardening tools the temper of which is not impaired by heat, and as a consequence may be driven much faster than carbon steel when used as machine-cutting tools.

Tungsten steel is capable of a higher degree of magnetization than any other steel. It resists atmospheric corrosion and the effects of sea-water to a remarkable degree.

A tungsten steel with 5–6 % tungsten is very hard and tenacious, but workable; with 10–12 % tungsten the steel is so hard that it cannot be worked with the lathe, and has therefore to be forged or ground.

ORE CONCENTRATION.

Tungsten ore, often associated with numerous other minerals, is usually separated from these and concentrated by some process of wet-dressing. This concentration often results in an accumulation of other heavy minerals with the tungsten ore, and further treatment is necessary to make a marketable product. Wolfram ores are usually slightly magnetic, and in this case can be removed by means of an electro-magnetic separator. The losses in dressing tungsten ores are often high on account of the production of excessive slime.

METALLIC TUNGSTEN.

Great care has to be exercised in the production of metallic tungsten at every stage in order to minimize heavy losses of valuable material. Tungsten is produced in round shapes from 0.080 wire up to ½-in. rods, also in sheets for special purposes if so desired. The metal is a pure, wrought, ductile, fibrous substance, and may be welded at a yellow heat.

TECHNICAL CHARACTERISTICS.

Density, 19.3 to 21.4.

Melting-point, 3177° C.

Boiling-point, 3700° C.

Specific heat, 0.0358.

Hardness, 4.5–8.0 (Moh's scale).

Insoluble in HCl, H_2SO_4, HNO_3, NaOH, KOH (aqueous), $K_2Cr_2O_7 + H_2SO_4$. Soluble in mixtures of HF and HNO_3 and in fused nitrates, nitrites, and peroxides.

Cast tungsten, or that in the form of powder, has properties differing widely from the pure wrought metal used in the production of metallic filaments, etc.

The manufacture of the tungsten filament lamp called for a very pure product, and this was rendered possible by a chemical method of extraction and purification of tungstic oxide (WO_3). This tungstic oxide is in turn converted to the pure metal by heating in a current of pure hydrogen in a temperature of 1200° C.

MANUFACTURE OF PURE TUNGSTEN METAL.

Briefly, the method is as follows :—

(1) Treating the refined ore.
(2) Roasting.
(3) Leaching the roasted ore.
(4) Precipitation of commercial tungstic acid.
(5) Purification of tungstic acid (H_2WO_4).
(6) Pure tungstic oxide (WO_3).
(7) Reduction of WO_3 to tungsten powder.
(8) Conversion to bars by pressure.
(9) Sintering of bars.
(10) Swaging and drawing.

(1) *Treating the Refined Ore.*—The wolfram concentrate is crushed to powder, mixed with commercial soda-ash, 1 part WO_3 content to 1 Na_2CO_3, plus 15 % excess soda ash, and reduced in an Abbé pebble mill to pass 100-mesh screen.

(2) *Roasting.*— The fine mixture is charged into a reverberatory furnace, hand-rabbled for 2 hours at a temperature of 800° C., and raked out to cool

Reaction — $2FeWO_4 + O + 2Na_2CO_3 = 2Na_2WO_4 + Fe_2O_3 + 2CO_2$.

(3) *Leaching the Roasted Ore.*—The cooled mass is crushed to pea size, transferred to wooden tanks, agitated overnight, filter-pressed, and clear filtrate of Na_2WO_4 discharged to precipitating tanks.

(4) *Precipitation of Commercial Tungstic Acid.*—These tanks are of wood or stoneware, and the Na_2WO_4 is brought to boiling temperature by live steam. A solution of $CaCl_2$ is then added, which throws down $CaWO_4$, according to the reaction—

$$Na_2WO_4 + CaCl_2 = 2\,NaCl + CaWO_4.$$

The $CaWO_4$ is baled to glazed ware bowls and treated with live steam and excess commercial HCl. The reaction $CaWO_4 + 2\,HCl = CaCl_2 + H_2WO_4$ takes place, and the H_2WO_4 is transferred to a suction filter and washed. It has the following composition:—

	%
H_2WO_4 ..	99.53
FeO	0.02
Al_2O_3 ..	0.05
CaO	0.20
SiO_2 ..	0.20

and is impure compared with the required acid.

(5) *Purification of Tungstic Acid.*—The washed precipitate is treated with ammonium-hydrate and live steam in an enamel-lined steel tank beneath a hood. The H_2WO_4 goes into solution as ammonium paratungstate—$5(NH_4)_2O, 12\,WO_3, 11\,H_2O$. The liquor is decanted to a special filter press, evaporated to small bulk, and dried to mud in a suction filter.

(6) *Pure Tungstic Oxide* (WO_3).—The yellow tungstic acid is fused in silica crucibles in a gas-fired oven at 1000° C., and gives a product of the following analysis:—

	%
WO_3	99.96
Fe_2O_3	0.0075
Al_2O_3	0.016
CaO	0.028
P	—
SiO_2	—
S	—

A very pure tungstic oxide has been produced in small quantities for special purposes with the following analysis :—

	%
WO_3	99.995
CaO	0.005

The metal tungsten is of higher purity than the above, due to volatilization of impurities. All oxides above 0.02 % Fe_2O_3 are returned for purification. About 40 % of the present output of the metal is derived from scrap tungsten.

The efficiency of the chemical process is 90 %—*e.g.*, 90 % of the tungsten in the ore is recovered.

(7) *Reduction of WO_3 to Tungsten Powder.*—The two commercial methods of reduction were (*a*) by hydrogen, (*b*) by use of carbon. The latter was generally employed owing to the difficulty in completing the reaction with hydrogen, but resulted in an impure product. The hydrogen method has been so improved that it has practically superseded the carbon method. At the Fansteel Products Company 10,000 cub. ft. of pure hydrogen are consumed daily in the process.

The WO_3 powder is placed in nickel boats on nickel trays in a closed tube type electric furnace and heated to about 1200° C. in an atmosphere of hydrogen. The reaction $WO_3 + 3H_2 = W + 3H_2O$ takes place, and the tungsten is withdrawn as a grey powder.

(8) *Conversion to Bars by Pressure.*—The grey powder is placed under a hydraulic pressure of 300 tons and formed into a bar of average size 1 in. sq. by 8 in. long, which might be termed cast tungsten. At this stage it is very fragile.

(9) *Sintering of Bars.*—The bars are placed between contacts in the sintering furnace in an atmosphere of dry hydrogen, and subjected to a current of 2750 amp. at 220 volts single phase. Considerable shrinkage takes place in the bar, and an intimate union takes place between the minute crystals of tungsten.

(10) *Swaging and Drawing.*—The sintered bars are now heated in an alundum tube, surrounded by a jacket of hydrogen. The furnace is heated to 1500° C. by a coil wrapped round the refractory tube. The bars are alternately heated and drawn until reduced to the required size either as bar or heavy wire.

USES OF TUNGSTEN.

These may be classified under three heads—

(1) Ferro-alloys.
(2) Filament lamps.
(3) Miscellaneous uses.

(1) FERRO-ALLOYS.

The old Damascus steel, celebrated for its retention of temper, has been found to contain both tungsten and chromium, although probably not intentionally added.

In 1900, high-speed tool steels containing tungsten and chromium, manufactured at the Bethlehem steel works, were exhibited at the Paris Exhibition, and created extreme interest among those familiar with metal working. These tools, by suitable heat treatment, could be used for cutting up to a temperature of 300° C. without losing their cutting edge. This temperature would ruin any carbon steel tool. Their efficiency is from three to five times that of carbon steel for cutting tools.

Ferro-Tungsten.—This alloy can be prepared by several methods—*e.g.*, (1) the direct reduction of the ore by means of carbon in a crucible; (2) by reducing in the electric furnace with carbon as a reducing agent. There are several other methods, but (2) is the one in general use. The product usually contains more carbon than is desired, and is de-carburized by means of refining slags.

The following is an analysis of ferro-tungsten obtained by reduction in the electric furnace:—W 79.48 %, Fe 18.60, C 1.49, Si 0.16, Mn 0.21, P 0.017, S 0.016, Al 0.001.

Tungsten Steel.—Mushet, in 1857, patented several methods for producing tungsten steel, and did more than anyone else to perfect it. He manufactured tool steel for many years under the name of "Mushet's metal," and his type of self-hardening steel was not surpassed for 33 years.

High-speed steel of modern kind had its birth in 1901, and soon revolutionized machine-shop practice. Mushet made a steel that could be heated with impunity, but would only cut effectively up to a temperature of 350°–450° C. It was found that an increased percentage of tungsten, combined with chromium, produced a steel which would cut even when a temperature of 650°–750° C. was attained.

All high-speed steels belong to one of two classes—"special" steel, containing about 18 % tungsten, and ordinary tungsten steel, with about 14 % of this alloy, in either case with small quantities of other elements.

Manufacture.—High-speed tool steels are made either by the crucible or by the electric-furnace method. The tendency of makers is in the direction of a somewhat uniform composition with respect to the alloying elements whose benefits have been proved, and may be considered fairly well established.

Theory of Tungsten Steel.—Arnold and Read concluded that the carbon in steel was combined with the iron when the tungsten was low; but the higher the tungsten the less carbon was combined with the iron, until in steel containing 11.5 % tungsten the whole of the carbon was combined with the tungsten, and none of it with the iron. With higher tungsten content the excess tungsten was combined with the iron. There are so many factors that affect the value of rapid tool steels besides the ultimate composition that no conclusion can be drawn from the analysis alone. The melting, hot working, and heat treatment all must be done correctly or the final product will not conform to expectations.

Result of analysis of a high-speed steel made in 1913 or 1914:—

	%
Carbon	0.75
Manganese	0.28
Silicon	0.36
Sulphur	0.03
Chromium	4.10
Tungsten	19.0
Vanadium	0.75

(2) METAL FILAMENT LAMPS.

In order that a metal may be suitable for use as a filament for incandescent electric lamps it is essential that it should have a high melting point, be fairly ductile, and possess a low vapour tension under working conditions.

It has been shown that the light emitted by an incandescent metal varies as the twelfth power of the temperature, whilst the energy required varies as the fifth power of the temperature. It is seen, therefore, that a small increase in the working temperature of the filament is of considerable advantage. Amongst the advantages possessed by metal filaments over those of carbon is that, being good conductors of electricity, their resistance increases with temperature, whereas with carbon filaments an increase of temperature causes a decrease of resistance, as the substance is a poor conductor of electricity. For this reason a fluctuation in voltage causes smaller alterations in the intensity of the light than would be the case if a carbon filament were employed.

The first metallic filament lamp was made by Welsbach in 1898, the man who invented the incandescent mantle for coal-gas lamps. Until that time the carbon filament reigned supreme. Briefly summarized, the transition from carbon to metal filament is as follows:—

(1) Carbon filament, with efficiency of 3 watts per candle power.
(2) "Metallized" carbon filament, with efficiency of 2.5 watts per candle power.
(3) Tantalum filament, with efficiency of 1.7 watts per candle power.
(4) Squirted tungsten filament, with efficiency of 1.25 watts per candle power.
(5) Drawn tungsten filament, with efficiency of 1 watt per candle power.
(6) Nitrogen-filled tungsten filament, with efficiency of 0.5 watt per candle power.

The many processes for the production of filament may be classified as follows:—(1) Substitution, (2) amalgamation, (3) squirting a paste containing tungsten, (4) squirting colloidal tungsten, (5) drawn wire, (6) alloy processes. Of these methods the chief are squirting and drawing.

(3) *Squirting a Paste.*—In this case the finely-powdered tungsten is mixed with a colloidal binder, such as gum, gelatine, etc. The paste is then forced through a nozzle, and the resultant thread heated to drive off carbonaceous matter.

(4) *Squirting Colloidal Tungsten.* Colloidal tungsten is prepared by the discharge of an electric arc between roughened tungsten electrodes under water. No binder is required in this case, and the resultant filaments are very strong and quite satisfactory.

(5) *Drawn Wire Filaments.*—Two methods are now in use for preparing the filaments viz., rolling and drawing.

Rolling.—Rolling is largely employed for producing wires not less than 0.03 in. in diameter. The bars of tungsten, whose production was described under the head of "Metallurgy," are passed between several pairs of high-speed rolls at decreasing distances apart. It is necessary to carry this out as far as possible in a current of hydrogen, with constant re-heating to prevent undue strains.

Drawing.—This operation is employed when wires of less than 0.03 in. are required, and calls for considerable skill on the part of the operator.

The rod or wire is heated sufficiently to make it ductile, and then passed through the draw-plate, which is heated and lubricated with deflocculated graphite. Repeated annealing is very necessary, as it has an important effect upon the crystalline structure of the tungsten. As the wire becomes thinner, the temperature to which it is heated is reduced. A rod may be heated in the first instance to 1600° C., and when reduced in diameter to 0.03 in. the temperature required is only 600° C., and finally the wire passes through the draw-plate at a dull red heat.

Properties of the filament.—As the wire is drawn out the tensile strength rises very rapidly, and the ductility also increases. This increased ductility also increases the resistance of the wire to damage by shaking or shock.

Tungsten filaments are also free from occluded gases, consequently the vacuum in the bulb is not impaired and the life of the lamp not decreased.

(6) *Alloy Processes.*—It has been found that filaments of pure tungsten are very liable to crystallize and develop other defects whilst in use. This may be prevented by the addition of a small quantity of thoria. The addition of thoria to the tungstic oxide during reduction facilitates the formation of elongated crystals in the metal. These crystals are very much more satisfactory than the irregular ones otherwise formed, especially when the metal is drawn into fine filaments, as used in electric lamps and thermionic valves.

Gas-filled Tungsten Lamps.—When investigating the cause of the blackening of filament lamps it was found that this defect, largely due to the volatilization of the filament, was minimized by introducing an inert gas into the bulb. The most suitable gas was found to be nitrogen. It was found that lamps made in this manner were much more efficient than the usual evacuated type.

(3) MISCELLANEOUS USES.

Hugo Lohman, a Berlin engineer, claims to have fused and cast metallic tungsten, and suggests the following uses for his metal :—Tungsten in the form of carbide, with a hardness of 9.8 (Moh's scale), could replace the diamonds which are employed in wire-drawing dies, as grinders for auger points, deep bores, and stone saws ; in the form of dust as aids to these operations, as glass cutters, etc. Fused tungsten can be cast in the form of pipes or crucibles. It is very resistant to acids, and the manufacture of acid-proof vessels for chemical purposes should find a wide market. The high melting-point also suggests the employment of tungsten in the making of crucibles. Lohman also considers that tungsten will eventually dominate the tool-making industry, tools of all sorts being made from pure tungsten in place of the alloys of this metal with steel or other metals.

Wire for incandescent lamps is made from powdered tungsten by pressing and sintering. If a molten form of tungsten were at hand for making filaments, the amount of current required per unit of light could be reduced, since fused tungsten is more effective as an incandescent resistant.

Tungsten, owing to its hardness, heat conductivity, and lower vapour pressure, is replacing platinum and platinum-iridium alloys in contact points, spark coils, voltage meters, telegraph instruments, etc. A saving in platinum has been made by the use of gold-coated tungsten dental pins. Electric furnaces (laboratory) with resisters of tungsten are used. Other furnaces use a tungsten metal tube to take the place of the helical carbon resister in vacuum furnaces.

Tungsten gauze, which is acid and alkali-resisting, is useful for separating solids from liquids. The gauze has been used for the electrostatic precipitation of fumes.

Wrought tungsten targets for X-ray tubes are now generally used on account of the high density of the metal. The tungsten is sometimes used with a backing of silver or copper, which conducts the heat away more rapidly.

Finely-divided tungsten is said to be an excellent catalytic agent in the production of ammonium from nitrogen and hydrogen.

Owing to its chemical stability, and the fact that it can be drawn to 0.0001 in. in diameter, it would be useful for galvanometer suspension and cross hairs for telescopes.

It has also been suggested to use thin wires in surgical operations in place of the coarser gold and silver wires.

Tungsten bronzes are produced by fusing tungsten with pure tin. These are resistant to ordinary acids, and used for decorative purposes.

The dye industry employs tungsten for fireproofing cloth and as a mordant for silks; the salt has the added feature of serving as a weighting material.

In the ceramic industry the tungstic oxide is used for producing yellows in glass and porcelain.

In the chemical industry, besides various utensils previously mentioned, the wire and sheet, being impervious to alkali solutions and to cold and hot acids, to a great extent, should find many practical applications, such as wire gauze for filtering acids, wire mesh for supporting filter cloths; in instrument parts where subjected to fumes from the process, and as supports for incandescent mantles.

Many useful alloys other than those with steel have been made, amongst which are the following:—

Partinium, an alloy of tungsten and aluminium, used by the French in automobile construction because of its lightness and strength.

Aluminium can be hardened with tungsten. Its resistance to oxidation makes it much superior to copper.

Platinoid consists of 60 % copper, 25 % zinc, 14 % nickel, and 1 to 2 % tungsten. It has a high electrical resistance, which does not decrease with heat.

An alloy of tungsten, aluminium, and copper is used in the manufacture of propeller blades.

Tungsten-molybdenum alloys, varying in composition from pure tungsten to pure molybdenum, are made in the same way as ductile tungsten. They are all ductile and malleable, and are being used as substitutes for platinum in dentistry.

An alloy of 20 to 60 % tungsten and 80 to 40 % platinum is used in electrical contacts, jewellery, etc.

Stellite is an alloy of 75 % cobalt, 20 % chromium, and 5 % tungsten. This alloy has some very valuable properties for cutting tools.

The war brought forth the demand for the thermionic valve in large quantities. The General Electric Company's lamp works at Hammersmith reached an output of 4000 valves per week. This is not only used as a wireless detector, but also in connection with wireless direction finding, and special wireless work on submarines. As before mentioned, tungsten filaments are remarkably free from occluded gases, and this is one of the chief reasons for its use in thermionic valves.

Gas-filled thermionic tubes have found application as low voltage rectifiers, for the charging of small batteries of accumulators from the usual alternating current supply.

Mr. M. C. Mott-Smith, writing to the *Scientific American*, puts forward an interesting suggestion in regard to an extension of the use of tungsten. According to him, if tungsten or some other highly refractory metal could be produced cheaply enough, cast in pieces large enough, and shaped as desired, we could build a practical gas-turbine. If the blades at the high-pressure end of such machine, and possibly the casing or lining of it at this end could be made of a highly refractory metal, so that a constant stream of gas at, say, 1000° C. could be directed upon the blades without injury to them, a wonderfully efficient engine would be obtained. A temperature dropping from 1000° C. to 100° C. would give a theoretical efficiency of 72 %. If only two-thirds of this were realized, the actual efficiency would still be nearly 50 %, which is much beyond that of any existing engine. To this advantage would be added increased lightness and compactness. Steam turbines are already far lighter and more compact than reciprocating engines of the same power. With an internally-fired turbine the boilers and furnaces are unnecessary, making a great saving in space and weight.

The uses herein mentioned or suggested cover a very wide field, which is doubtless not yet thoroughly explored, and it appears evident that an increase in consumption of tungsten must necessarily follow as research develops further uses for this metal.

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PART II.

KING ISLAND SCHEELITE TREATMENT.

INTRODUCTION.

LIKE many other tungsten properties, the King Island Scheelite Co. was brought into being by the great demand for this metal during the war. The bulk of the tungsten was required for ferro-alloys, and the demand created considerable activity among the producers of tungsten ores. Australia, during the war, sent the whole of its tungsten product to the British Government at 50 % less price than that ruling in the world's market.

The King Island Scheelite Co. was registered in February, 1917, and in July of the same year commenced the production of a high-grade scheelite concentrate.

SITUATION.

King Island is situated in Bass Strait, to the north-west of Tasmania, about midway between Cape Grim and Cape Otway. The island has a length of about 40 miles and a width of 16 miles. The area held by the company occupies a portion of the south-eastern end of the island adjoining the coast.

Access to the mine is given by road from Currie, the principal settlement, situated on the west coast of the island. The distance from Currie is estimated at 18 miles. The mine is situated within a mile of the southern end of a wide bay, at which point a jetty is now under construction. The rock here is granite, and there is an ample depth of water for the type of boat calling at the island. There is also a fine jetty at Fraser Bluff, situated on the east coast, and distant about 17 miles from the mine.

TOPOGRAPHY.

The topography of the locality is of such a character as to be favourable for mining operations, and consists of a plateau rising to about 400 ft. above sea-level. The seaward slope is steep, and has been considerably modified by the erosive action of various streams. The principal stream in this locality is the Grassy River, which flows a little east of south, and has cut its gorge down to sea-level. It is from this stream that the water is pumped to the mine for ore-dressing and other purposes.

The deposit was discovered outcropping on the beach, and advantage was taken of the topography in prospecting the formation by driving adits in the slope of the hill.

Rainfall.

The rainfall on the island is about 35 in., and is well distributed throughout the year.

Timber.

Although there is not much green timber in the vicinity of the mine, there is abundance of dry timber standing. This was killed by a bush-fire which swept the island about 30 years ago. The dry timber forms a valuable firewood supply, and is tapped by a tramway for that purpose.

Geology and Mineralogy.*

Rock Formation.—Both igneous and sedimentary rocks are represented in the neighbourhood of the mine; the latter occupy the bulk of the area of the lease, the south-eastern corner of which is on the contact of the granite and sedimentary rock. Granite outcrops for 7 or 8 miles along the coast to the south of the mine, and appears to extend inland for at least 2 miles. Old slates and sandstones extend to the north for some distance.

Granite.—The granite, which is of the porphyritic biotite type, is very fresh, and shows no signs of crushing. At the contact, granite-porphyry occurs, with occasional large crystals of pink orthoclase felspar. It is traversed by occasional dykes of granite-porphyry and of aplite, representing, probably, later phases of the igneous intrusion.

Aplite.—Closely associated with the scheelite lode is a dyke of aplite, undoubtedly connected with the granite. It is composed essentially of quartz, with some decomposed felspar and aggregates of muscovite-mica. It carries both molybdenite and scheelite in places. An analysis shows the following composition :—

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* After L. L. Waterhouse, B.E., late Assistant Government Geologist, Tasmania, abstract Geological Survey, Mineral Resources, No. I.

	%
$H_2O -$ =	0.68
$H_2O +$	0.62
SiO_2	62.81
Al_2O_3	24.02
FeO	0.60
Fe_2O_3	0.32
TiO_2	absent
MnO	0.03
CaO	1.41
MgO	0.20
Na_2O	6.31
K_2O	2.97
Total	99.97

Specific gravity = 2.60.

Sedimentary Rocks.—The scheelite occurs in the sedimentary rocks, but within about 12 chains of the margin of the granite massif. As is to be expected in such close proximity to the intrusive granite mass, the old sedimentary rocks are intensely altered. They appear sometimes as spotted schists, sometimes as very hard, black, flinty hornstones. Microscopical examination of sections of these rocks shows the development of quartz, albite, sericite, chlorite, biotite, and magnetite.

Water-Worn Deposit.—An interesting occurrence of water-worn gravel and shingle was noted in the open-cut at an elevation of about 130 ft. above sea-level. The shingle consists mainly of quartzites and fragments of rock similar to those found in the adjacent country. It may be a remnant of river gravel accumulated by some stream when the surface contour was different to that of the present day, but more probably it forms part of a deposit of beach shingle. The land surface in this vicinity represents an old pene-plained area which had been worn down approximately to sea-level and subsequently uplifted by earth-movements. The shingle observed may have attained its present position either by a single movement or several movements amounting to 130 ft.

NATURE OF THE ORE-BODY.

Mineralogical Composition.—The ore consists essentially of garnet, usually in well-formed crystals. Other gangue minerals observed were quartz, epidote, calcite, monoclinic pyroxene, and actinolite.

The metallic minerals noted were scheelite, molybdenite, pyrite, and bismuth.

Scheelite (tungstate of lime, $CaWO_4$).—This is undoubtedly a primary mineral. It occurs both in amorphous masses and in definite crystals. The largest crystal observed measured over an inch across. The scheelite frequently occurs in quartz-veins traversing the garnet formation and aplite. In several instances molybdenite was noted included in the heart of scheelite crystals, while in other cases masses of scheelite were surrounded by a rim of molybdenite flakes.

Molybdenite.—This mineral occurs mostly in the quartz-veins which traverse the garnet formation. There is not sufficient of it in the lode to make it of economic importance.

Pyrite.—Pyrite is present in small quantities only, and insufficient to be detrimental to the production of a high-grade concentrate.

Bismuth.—Several small fragments of native bismuth were obtained in one part of the workings, but the average value of 25 mine samples was only 0.0126 % metallic bismuth.

Garnet.—The variety of garnet represented is of the lime-iron type known as andradite. It is usually reddish in colour, and translucent, and occurs in well-formed crystals up to about ¼-in. across. The garnet is attracted by the electro-magnet, and this property at once suggested a possible method of treatment. The garnet is further dealt with at a later stage (see garnet analyses).

MODE OF ORIGIN.

There can be little doubt, says Mr. Waterhouse, that the deposit is genetically connected with the neighbouring granite massif, and that the metallic constituents were introduced with the granite magma, differentiation causing a partial concentration of these constituents in the still molten magma. These were expelled as gases at an extremely high temperature, as the magma gradually cooled and consolidated, and penetrated the overlying sedimentary rocks which were at an extremely high temperature. The aplitic dyke may represent the main channel by which the metallic minerals were conveyed to their present position, the quartz and felspar representing granitic material which was expelled with the metallics from the cooling granite mass. It seems likely that the ore deposit was formed when the chemically active and metal-bearing vapours and solutions came into contact with calcareous beds, which were almost completely replaced, the metals being deposited. The outstanding features which indicate that some such theory must be postulated to explain the mode of origin are:—

(1) The banded structure of the deposit.
(2) The occurrence of bands of country rock altered to garnet-pyroxene outside the main body of the ore.
(3) The mineralogical composition of the ore, and especially the presence of so many lime-bearing minerals (scheelite, garnet, diopside, calcite, epidote, actinolite).
(4) The close association with the aplite dyke, which itself carries metallic values.
(5) The high-temperature minerals present.

MINING.

The facilities afforded by the topography in the vicinity of the ore deposit have, to a very large extent, determined the method of mining. This is carried out by the open-cut system. The overburden is worked down over the ore-face by the aid of explosives, when necessary, and is picked up by a steam navvy, loaded into side-tipping trucks of about 3 cub. yd. capacity, and run out to the tip. Owing to the configuration of the country, ample room is available for deposition of spoil.

Having cleaned up the face, the ore is then broken down in a similar way to the overburden, ropes being hung down the face at intervals to facilitate the movements and ensure the safety of the miners. The ore is picked up by the navvy (where distant from the chutes), loaded into the above-mentioned side-tippers, and trucked to the chutes. These connect up with adits driven into the hill at a lower level than the open-cut. From the chutes the ore is trucked to the bin at the head of the mill. Bars of aplite are occasionally encountered in the ore-body, and, on account of their hard and tough qualities, call for the use of something more powerful than the hand-drill. This is supplied by rock-drills, which are operated by steam, in the absence of a supply of compressed air.

TREATMENT.

Before consideration can be given to the treatment of an ore of this description it is necessary to have in mind its composition, and the characteristics of some of the minerals from which the scheelite has to be separated.

As already mentioned, the mineral which forms the bulk of the gangue is garnet. The average specific gravity of samples examined gave a value of 3.7. Its other outstanding features are its hardness (about 6.5) and its toughness.

The economically important mineral scheelite, on the other hand, has a specific gravity of 5.9. It is appreciably softer than the garnet, with a hardness of about 5. In addition to this, it is brittle.

With a hard, tough gangue mineral occurring with a softer and more brittle mineral to be concentrated, the objective is to remove the scheelite at the earliest convenient stage in order to minimize slime losses. The relatively small difference in specific gravity between the garnet, other gangue, and scheelite indicates the necessity for careful classification in order to obtain a satisfactory concentrate. From experiments carried out at an early stage in the development of the mine it was found that the garnet had a certain magnetic permeability, and was, moreover, the only magnetic mineral in the ore. It was also found that the ore carried about 70 % of garnet. A consideration of these facts indicated the lines upon which treatment might be successfully carried out.

Scheme of Treatment.—Briefly, the scheme was as follows:—Coarse crushing, tabling to remove such gangue minerals as quartz, aplite, etc., and the formation of a garnet-scheelite concentrate. This mixed concentrate to be passed under an electro-magnet to remove the garnet, leaving a marketable product of high-grade scheelite.

The scheelite occurs in minute grains disseminated through the garnetiferous mass, as well as in crystals of about the same size and larger than the garnet, and in amorphous masses several inches across.

Ore Grade.—The grade of the ore varies from 0.7 % WO_3 up to 1 % WO_3, and is oxidized to a varying extent. The ore does not lend itself to picking, being fairly homogeneous, and the grade is only likely to be adversely affected by admixture of overburden in a fine state of division. The larger waste-rock is kept out in the open-cut.

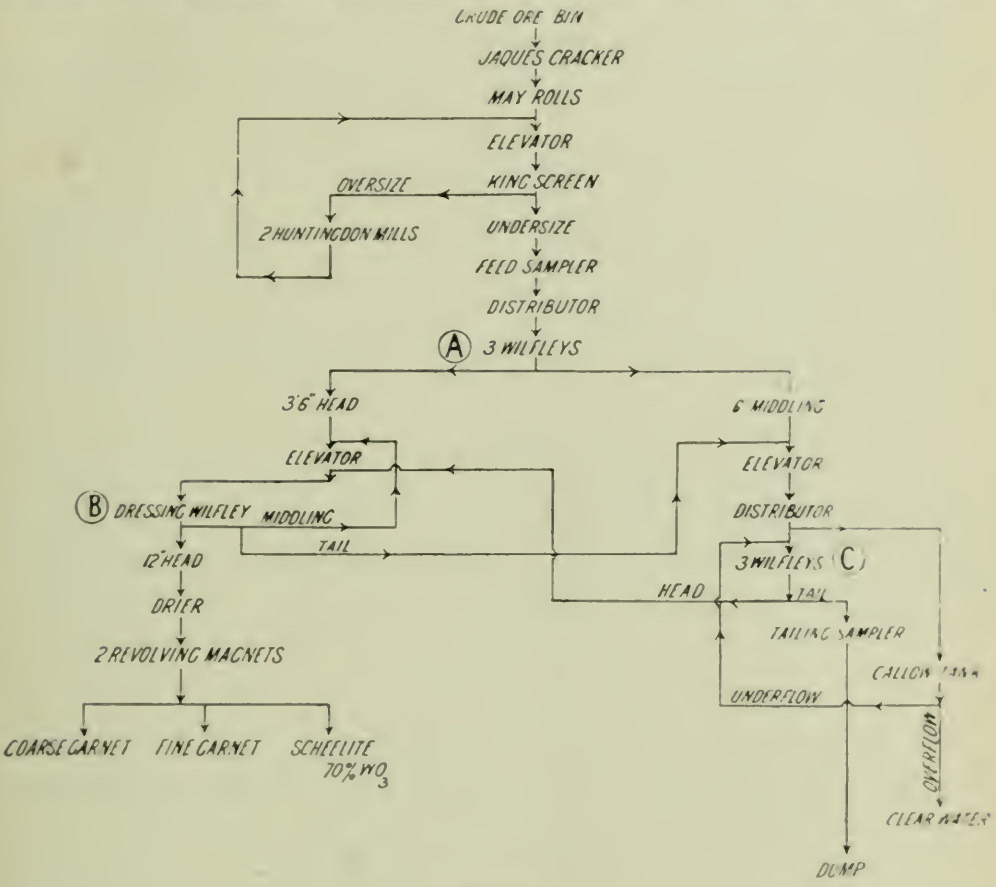

Fig. 1.

Flow Sheet.

Flow Sheet.—Reference to the above flow-sheet (fig. 1) will indicate the general scheme of treatment.

Coarse Crushing.—The ore is hand-fed direct from the bin to a Jaques cracker, which has ample capacity for the present tonnage of comparatively soft oxidized ore. The rate of feed is regulated by the cracker attendant in the absence of any automatic device, which would more than likely be rendered inoperative during the winter months.

Fine Crushing.—The rolls and Huntingdon mills are in closed circuit with the King screen, the oversize from the screen being returned to the Huntingdon mills. The discharge from the mills is carefully regulated to release the scheelite at the earliest moment, in order to make as little fines as possible.

Screening. The King screen is of the usual type, and does its work efficiently so long as close attention is paid to the screen.

Dressing and Concentration.

The Wilfley tables used in this section are supported on hardwood slats, and are not adjustable, being fixed at the angle found most effective on this type of feed.

The water used for dressing purposes is first passed through the surface condenser.

TABLES (A).

The three Wilfleys, marked (A) on the flow-sheet, take the feed from the King screen and make two products—a head which goes to the re-dressing Wilfley marked (B) on flow-sheet, and a middling which goes to the three Wilfleys marked (C) on flow-sheet.

TABLE (B).

This Wilfley is used for re-dressing a middling product or head from the other tables marked (A) and (C) on flow-sheet. It produces a scheelite-garnet concentrate of about 45 % WO_3, which is dried and passed under the electro-magnets. A middling product is returned to the same table, and a tailing to the tables marked (C) for further treatment.

TABLES (C).

These Wilfleys are re-treating a middling from tables (A), a tailing from the re-dressing tables (B), and an underflow from the callow tank, a considerable proportion of which is slime. They produce a middling product which is returned to table (B), and a tail, the only reject from the mill, which runs into the sea and is dispersed by wave action.

DRIER.

The scheelite-garnet concentrate, from the re-dressing table (B), is run into a box, from which it is shovelled on to one end of a drying furnace. The concentrate is gradually worked to the cool end of the furnace and then hand-screened, to remove any large particles which may have escaped the King screen.

These particles are returned to the Huntingdon mill. The drier is heated by means of firewood, the consumption of which is small.

ELECTRO-MAGNETS.

The screened concentrate is then bagged and transferred to the electro-magnets.

These consist of two revolving magnets operating over an endless belt, beneath which are the wound and insulated poles. The magnets are hung on ball bearings, and driven by spur gearing at 40 r.p.m. The diameter of the magnets is 22 in., and they have a depth of 4 in. The belt is of fine canvas, and before use undergoes a special treatment of oiling and drying, followed by a coat of shellac varnish. The belt passes over 12-in. drums, the rate of travel being 27 ft. per minute. The concentrate is fed from a hopper by means of a roller feed.

The air-space between the magnets and belt is so arranged that a coarse and fine garnet product is removed in two stages, and leaves on the belt a scheelite concentrate containing about 70 % WO_3. This is carried over the end of the belt, where it is bagged, weighed, and sampled. The garnet extract is returned to the mill as a protection against faulty work, which may be due to excessive feed to the magnets or incomplete drying of the mixed concentrate. The current supplied to the magnets is 240 volts, and three 50-c.p. lamps are placed in series as resistance.

SAMPLING.

The feed and tail samples are taken by a well-known automatic device, which cuts across the stream at regular intervals. It is operated by a flow of water. On this class of product an automatic device of this kind is much to be preferred to hand sampling. The scheelite concentrate, which is sewn up in calico-lined bags, is sampled by hand. A portion is taken from each bag as it is filled by means of a pricker.

ASSAY METHOD.

The methods of assay will be dealt with in the next section of the paper.

Screen Analysis. — The screen analysis was conducted under difficulties, owing to the dearth of screens on the island, but enough data was obtained to show where the scheelite values were located. The following facts are disclosed by an examination of the screen analysis given above.

Product.	Screen.	% Weight.	Assay Value % WO_3	% Garnet.	% Non-magnetic.
Feed from King Screen	Original Sample	100.0	0.88	66.0 (contains only 0.03 % WO_3)	34.0
	+10	4.6	0.95		
	+50	56.3	0.68		
	−50	39.1	1.17		
Middling from Wilfley (*b*)	Original	100.0	0.027	98.0	2.0
	+10	4.2	—	4.2	—
	+17	3.0	—	3.1	—
	+37	22.4	—	22.6	10.0
	+50	16.7	—	16.8	15.0
	−50	53.7	0.056	53.3	75.0
Final tail to dump	Original	100.0	0.06	—	—
	+10	3.05	0.18	—	—
	+17	5.40	0.15	—	—
	+37	19.44	0.09	—	—
	+50	13.48	0.05	—	—
	−50	58.63	0.03	—	—
Final concentrate	Original	100.0	68.00	—	—
	+10	0.8	64.00	—	—
	+17	1.9	69.16	—	—
	+37	13.2	71.46	—	—
	+50	15.6	72.80	—	—
	−50	68.5	66.02	2.5	—

FEED.

The sample of feed, 56.3 % of which remains on the 50 mesh, is the minus product from the King screen. This contains 66 % of garnet, which assays only 0.03 % WO_3, and is considerably below the tailing value. The presence of such a high proportion of garnet is suggestive of a method of treatment for removing this at an earlier stage, although it is quite possible that the heavy garnet gangue may assist materially in cleaning the scheelite on the tables. The average value of the feed is 0.7 % WO_3.

CONCENTRATE.

Owing to the greater hardness and toughness of the garnet as compared with the scheelite, together with the brittle nature of the scheelite, we are prepared to find the bulk of the concentrate in the —50 product (68.5 % of the final concentrate). Taking this in conjunction with the concentrate (see page 128) from the tables (A) and (C), it is evident that the values should be eliminated at the earliest possible stage to avoid slime losses. In the —50 product there is also a small proportion of garnet which is evidently mechanically retained by the scheelite when passing under the magnets.

This indicates the necessity for a regular, even, and thin bed of the mixed concentrate passing beneath the magnets to ensure the best results.

A gradual increase in the value of the sizings will be noticed from +10 to +50. The low value of +10 (64 % WO_3) is due, on inspection, to attached particles of gangue. The highest value is shown on the +50 (72.8 % WO_3), followed by a drop to 66.02 % WO_3 in the —50 product, due evidently to the fine garnet (2.5 %) and other fine gangue.

MIDDLING.

This product is from table (B), and discloses the interesting fact that the value in this product is less than that of the final tailing. This suggests the possible rejection of a portion of the middling at an earlier stage in the mill procedure. The values omitted in the products above —50 were too small for estimation by the methods in use during this test. It is also evident, from the value in the —50 product, how readily the brittle scheelite is reduced to a size which is productive of the greatest losses.

FINAL TAIL FROM TABLES (C).

The chief value in this product, as we would expect, is in the —50 portion. Part of this value is undoubtedly derived from the underflow from the Callow settler, and it is obvious that there is a certain amount of fine material carrying values which are not recoverable under the present system of treatment.

FEED TO MAGNETS.

This mixed concentrate showed, on assay, a value of 44.5 % WO_3, and is composed of 63.5 % scheelite and 36.5 % garnet. The final concentrate from this feed assayed 71.6 % WO_3.

UNDERFLOW CALLOW SETTLER.

The underflow from the Callow settler, which goes to tables (C), showed an assay value of 0.0114 % WO_3.

This settler is to some extent a safeguard in the event of a rush of feed coming on the tables. The overplus is then caught in the settler, and serves to some extent to regulate the feed to tables (C).

Summary and Conclusions.

The aim throughout the mill is to obtain a mixed concentrate of garnet and scheelite from which the other gangue is eliminated. The garnet is readily removed from this mixed concentrate by the electromagnet, giving a high-grade scheelite concentrate. A higher recovery could doubtless be made by taking off a lower-grade concentrate for treatment by the magnets, but this would entail a lower-grade final concentrate.

Trial Concentrates.—With this idea in mind, a mixed scheelite-garnet product was taken off tables (A) and (C), comprising a 4-in. sample from the discharge end of five tables. On drying and passing this under the magnets, 65.5 % of scheelite was left, assaying 68 % WO_3 and 34.5 % of valueless garnet. It is evident that the lower grade of concentrate is largely due to gangue other than garnet, which in the ordinary course of treatment would be removed on the re-dressing table (B).

Consideration of the flow-sheet and screen analysis are suggestive of a possible scheme of (1) re-treatment, or, on the other hand, (2) an alternative method to the present one.

(1) *Re-treatment.*—Any method of re-treatment would operate on the final tailing, as that is the only reject from the mill. The more

valuable portion of this (*vide* screen analysis) could be selected by screening, and the following operations would then be necessary :—

- (*a*) Grinding of portion of this, if necessary.
- (*b*) Elimination of any valueless slime.
- (*c*) Classification and thickening of feed.
- (*d*) Treatment of thickened feed on adjustable tables or vanners.
- (*e*) Drying and electro-magnetic treatment of mixed concentrate.

The value of such a scheme would depend upon—

- (1) The presence of skilled labour to operate tables or vanners, and
- (2) The price per unit of scheelite.

(2) *Alternative Treatment.*—The large proportion of garnetiferous gangue (from 60 to 70 %) indicates the necessity for its early removal in order to minimize wear and tear in reduction, etc., and to concentrate the values in a small bulk for treatment on fewer tables. The following is an outline of the scheme :—

- (*a*) Coarse crushing of ore.
- (*b*) Secondary crushers.
- (*c*) Screening.
- (*d*) Grinding of oversize by special design of ball or tube-mill to minimize production of fines.
- (*e*) Treatment on roughing tables or jigs to remove coarse gangue and produce a scheelite-garnet middling.
- (*f*) Wet magnetic treatment of middling to remove bulk of garnet.
- (*g*) Classification, grinding of portion of the remaining product, thickening, and treatment on adjustable tables or vanners.
- (*h*) Continuous mechanical drying of feed to magnets.
- (*i*) Automatic weighing, sampling, and bagging of final concentrate.

Any scheme of treatment as outlined above would be subject to modification by experiments carried out on a working scale.

Tonnage.

For the six-monthly period ending 31st March, 1920, 15,823 tons of ore were sent to the mill for treatment, averaging 0.67 % WO_3, which produced 121 tons 7 cwt. of concentrate, averaging 69.6 % WO_3, representing a recovery of 79.5 %.

Costs.

For the same period the costs were :—

	s.	d.	
Ore extraction	3	4.61	per ton of ore mined.
,, treatment	6	7.19	,, ,,
Development	0	3.02	,, ,,
Overburden removal	3	6.29	,, ,,
General expenses	0	4.17	,, ,,
Total	14	1.28	,, ,,

Garnet Analyses.

	King Island Garnet.		Broken Hill Garnets and Garnet-Sandstone.		
Constituents.	Coarse Product, 1920.	Fine Product, 1920.	Lode Garnet, 1920.	Country-rock Garnet, after C. H. Mingaye, 1919.*	Block 14, Garnet-Sandstone, 1920.
	Andradite.		Spessartite.	Almandine.	Spessartite type.
H_2O(hygroscopic)	0.03	0.02	0.03	0.04	0.24
H_2O (combined) ..	0.37	0.36	0.30	0.58	0.30
SiO_2 ..	34.83	34.00	35.20	38.12	38.12
Al_2O_3 ..	2.84	4.01	21.54	19.71	19.82
Fe_2O_3 ..	25.35	24.34	1.25	6.70	2.00
FeO ..	1.72	1.26	12.37	27.63	6.84
MnO ..	1.28	2.06	24.88	2.05	27.96
CaO ..	32.26	32.61	3.45	1.14	4.38
MgO ..	trace	0.42	0.78	3.22	0.16
Na_2O ..	0.17	0.18	0.08	0.69	0.18
K_2O ..	1.10	1.00	0.69	trace	0.66
TiO_2 ..	0.26	0.34	0.19	0.47	0.26
Li_2O ..	—	—	—	trace*	—
Cr_2O_3 ..	—	—	—	trace	—
WO_3 ..	—	0.26	—	—	—
Total ..	100.21	100.86	100.76	100.35	100.92
Sp. gr. ..	(3.66-3.88)	3.55	4.18	—	—

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* Spectroscopic re-action.

Garnet Analyses.

Owing to the importance of the garnet, which forms 66 % of the lode, it was decided to carry out some analyses. In order to increase the interest to members of the Broken Hill branch, I have included analyses of local garnets and garnet-sandstone. With the exception of a country-rock garnet by C. H. Mingaye,* which was included for purposes of comparison, the analyses shown in this paper were carried out in the Block 14 Assay Office.

Amongst the points to be settled by analysis were the following :—

(1) The type of garnet.
(2) Whether the coarse and fine garnet reject from the electro-magnets were of the same composition ; and
(3) If the WO_3 shown in the fine garnet was in combination, or mechanically adhering as scheelite dust.

Andradite (*Lime-Iron*). From an inspection of the analyses on p. 132, it will be seen that the coarse and fine garnet are practically identical, and they conform to the lime-iron type known as andradite.

According to Dana, the colour of this type varies from wine, topaz, greenish-yellow, apple-green, brownish-red, brownish-yellow, greyish-green, brown, greyish-black, to black. It has a hardness of over 7, and a specific gravity of 3.64–4.0. Rutley gives its specific gravity as 3.44 and approximate composition as $SiO_2 = 36$, $Fe_2O_3 = 30$, $MnO = 3$, $CaO = 29$, and $K_2O = 2$.

Spessartite (*Manganese-Alumina*). Of the Broken Hill garnets, the lode-garnet corresponds to the manganese-alumina or spessartite type. Dana gives an analysis of $SiO_2 = 36.16$, $Al_2O_3 = 19.76$, $FeO = 11.19$, $MnO = 32.18$, $MgO = 0.22$, $CaO = 0.58$, $= 100$.

The colour of this variety is a dark hyacinth-red, sometimes with a shade of violet, to brownish-red. It is slightly translucent on the edges, and has a vitreous lustre. Its fracture is imperfectly conchoidal. Its hardness is 7–7.5, and specific gravity 3.6–4.4.

Almandine (*Iron-Alumina*). The Broken Hill country rock garnet corresponds to the iron-alumina type or almandine, with an approximate composition $SiO_2 = 36.1$, $Al_2O_3 = 20.6$, $FeO = 43.3$; or manganese may replace some of the iron and iron part of the alumina. Its colour is from fine deep red to brownish-red, and its lustre vitreous. Its fracture is sub-conchoidal or uneven, and streak white. Its hardness is from 6.5–7.5, and specific gravity from 3.7–4.21.

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* Annual Report, Dept. of Mines, N.S.W., 1919, p. 186.

Garnet Sandstone.—The garnet sandstone, as would be expected, corresponds to the lode garnet of manganese-alumina or spessartite type, and therefore of secondary origin.

It will be noticed, on reference to the garnet analyses, that the fine King Island garnet contains 0.26 % WO_3, whilst there is no WO_3 in the coarse variety. The question then presented itself as to whether the WO_3 was in combination or carried over mechanically with the fine garnet.

After careful tests, involving vanning, drying, and treatment by the electro-magnet, it was found that the amount of WO_3 in the garnet was appreciably reduced.

Separate crystals of garnet were carefully cleaned and examined qualitatively for WO_3, with negative results.

Samples of the garnet were examined microscopically by Mr. T. A. Read, of the Broken Hill South mine, but he was unable to note the presence of scheelite in the garnet.

From the above experiments it was concluded that the WO_3 found in the fine garnet is mechanically carried over by the garnet, probably adhering as scheelite dust.

Outlook for Tungsten Mineral.

The King Island scheelite mine was compelled to close down in August, 1920, due to the extremely low price ruling for tungsten. The price received from the Imperial Government for concentrate during the war was 52/6 per unit f.o.b. at the mine. The London quotation for 9th August last was 26/6 per unit delivered in London. The estimated expense for freight, insurance, commissions, and realization approximate 8/- per unit, leaving a balance of 18/6 per unit wherewith to pay all costs of mining, milling, managerial, and other expenses. It is estimated that it costs 35/- per unit to produce the concentrate, and it takes an average of about 110 tons of ore to produce one ton of 70 % concentrate.

Since the company commenced production, in July, 1917, 67,352 tons of ore have been raised, producing 612 tons of high-grade scheelite concentrate, of which 569 tons, valued at £95,142, have been taken delivery of by the Imperial Government, leaving a balance of 43 tons now stacked at the mine.

G. J. Young, writing in the *Engineering and Mining Journal* of 17th January, 1920, on the tungsten mining industry, says:—"The opening-up of China as a tungsten-producing country brought the world's production in 1918 to well over 30,000 tons, or about four times the pre-war figure. Early in 1917 supply and demand were about equal. The Chinese ore can be delivered in the United States at a price at which no home mine ore can compete. The proved Asiatic production costs do not exceed 2 dollars per unit. After paying taxes, freight, brokerage, and other charges, the Asiatic tungsten ores are to-day being sold in New York at 6 dollars per unit. There is no question that the price of foreign ores will increase to probably just below our production cost, or even up to our production cost. The Chinaman is shrewd enough to regulate the taxes or 'squeeze' so as to approximate the price on our markets."

A quotation from Vice-Consul Carl C. Hansen, at Bangkok, published in *Beama*, April, 1920, states that the potential production of tungsten metal is unlimited, and that the ore is widely distributed throughout the Siamese Malaya and Northern Siam. The metallurgical outlook, therefore, from the point of view of tungsten alloys is encouraging. At present production has practically ceased in these countries.

It looks as though the future for tungsten mineral will be found in an increased consumption of the metal resulting from a growing recognition of its many varied and useful qualities. The present low price of the metal will doubtless have the desired effect of directing attention along these lines.

PART III.

ASSAY OF LOW-GRADE MATERIAL.

THE ESTIMATION.

TUNGSTEN is estimated gravimetrically, for the reason that no suitable, reliable, volumetric or colorimetric method has been evolved.

The form in which tungsten is estimated is the trioxide WO_3, and this is precipitated either from solutions of mineral acids or thrown out of solution by such precipitants as mercurous nitrate, cinchonine, or benzidine. The estimation is based on the fact that the yellow modification of tungstic acid is practically insoluble in dilute mineral acids, and soluble in ammonium hydrate or caustic alkalies. This principle has been successfully applied to high-grade ore or concentrate, but in dealing with low-grade material the precipitation of WO_3 is more or less incomplete. Below a certain concentration the change to the yellow modification does not readily take place, and there is a pronounced tendency of the WO_3 to form stable soluble complexes with a number of elements, as mentioned under "Chemistry" (section 1).

This tendency is increased when the solution is taken to dryness, and often tungsten has been reported absent, on this account, even when present in appreciable quantities.

DEVELOPMENT OF THE METHOD.

The tungsten estimation has developed along the following lines:—

1. *Aqua Regia Methods.*—These involved an attack with acids, sometimes combined with hydrofluoric acid, oxidation, and precipitation of WO_3 in nitric acid solution, solution of the WO_3 by ammonium hydrate, evaporation, and subsequent ignition of ammonium tungstate to WO_3.

2. *Mercury Methods.*—The attack was by acid, or fusion with alkalies, WO_3 precipitated by mercurous nitrate, and mercurous tungstate ignited to WO_3.

At a later period attack by caustic alkali was successfully applied.

3. *Cinchonine Methods.*—In these methods a dilute hydrochloric acid solution of cinchonine was the precipitant, and the method of attack might be either by (*a*) acid, (*b*) digestion with caustic alkali, or (*c*) fusion.

(*a*) Acid Attack.—This followed the lines of the aqua regia methods, with the exception of the use of hydrofluoric acid.

(*b*) Digestion with Caustic Alkali.—This is a more or less selective attack, wherein the tungsten is brought into solution as an alkali tungstate.

(*c*) Fusion.—This may be carried out in platinum, nickel, silver, or silica crucibles or dishes, depending on impurities in the charge, its amount, and the fusion agents. These latter might be either sodium carbonate, fusion mixture ($Na_2CO_3 + K_2CO_3$), sodium peroxide, potassium bisulphate, sulphur, etc.

Various modifications of the above have been evolved to meet special cases, and no one method can be advocated as suitable for all ores. Each ore requires separate study, and where any quantity of it has to be dealt with it should be carefully analysed to determine the interfering elements that may be present.

A method which may be eminently suitable for a high-grade ore or concentrate might obviously be quite unsuitable for an ore or residue carrying less than 0.5 % WO_3. The bulk of the available methods are designed for high-grade ore, or concentrate, and applied in that respect are well established and satisfactory.

In dealing with low-grade ore and mill products, such as those of the King Island scheelite mine and mill, certain methods suggested the possibility of successful treatment and reliable results. With a residue running as low as 0.1 % WO_3, it was quite evident that no reliance could be placed on methods which involved the treatment of less than 5 grm. of the material. This factor practically decided the type of method which was likely to prove most suitable.

KING ISLAND METHOD.

The method evolved on the mine for the assay of low-grade ore and mill products embraced the procedure as applied to the assay of the concentrate, together with a preliminary vanning and magnetic treatment, to remove the bulk of the gangue. The only advantage of this method lay in the fact that a large quantity of the material could be taken for assay. The success of the method depended to a large extent on the skill of the man using the pan, and, although an experienced operator might get concordant results, one would expect them to be on the low side, due to mechanical losses in panning and magnetic treatment.

The procedure is as follows for feed and tailings :—In the case of feed, 100 grm. are taken ; for tailings, 1000 grm. The sample is crushed to pass a 40-mesh screen, concentrated by vanning to small bulk or until the maximum amount of non-magnetic gangue is removed, dried, and passed under the electro-magnet to remove the garnet. The residue is crushed very finely in the agate mortar, brushed into a casserole, and 50 cc. strong HCl, together with 10 cc. of a 10 % potassium nitrate solution, added. The assay is stirred to prevent particles adhering to the bottom of the casserole, heated at moderate temperature until decomposed, evaporated to approximate dryness, re-treated with strong HCl, and again evaporated to apparent dryness. Re-treat with strong HCl, dilute, heat, and filter ; wash well with 1 % solution of HCl. Pour over the filter dilute ammonium hydrate, and then a few drops of strong ammonium hydrate till all WO_3 is in solution, catching the filtrate in a weighed platinum dish. Evaporate to small bulk on water-bath, add excess of strong NH_4HO, and evaporate carefully to dryness. Heat residue carefully to drive off ammonium salts, then to a red heat until the WO_3 is a canary-yellow colour. Avoid overheating, weigh until constant, and report as tungstic oxide, WO_3. Triplicate assays on a sample of tailings gave the following results :—0.09 % WO_3, 0.08 % WO_3, 0.086 % WO_3.

MILL METHOD.

As a rapid and approximate method for use in the mill, the above might be applied up to the point of the magnetic treatment, when the residual scheelite could be weighed and calculated to WO_3, a correction factor being applied for the impure concentrate. The weak point of the King Island method, in keeping with other aqua regia methods, is its liability to low results due to retention of WO_3 in the acid liquors of the assay. In order to test this point, an assay was made on King Island tailings by the acid method, taking a 5 grm. charge. The amount of WO_3 found was 0.244 %. The acid liquors were treated with cinchonine, and gave a further 0.028 % WO_3, making a total of 0.272 % WO_3.

Amongst the numerous methods investigated by the writer in the quest for a suitable one for the King Island ore and residues, those of H. W. Hutchin * seemed to offer most promise.

Several of these permitted the use of the maximum amount of ore for assay, and employed a solution of cinchonine as the precipitant for WO_3. Cinchonine was selected in preference to mercurous nitrate, as, from experimental work, it appeared to give a more complete precipitation of the WO_3, and the precipitate was a better one to manipulate. The disadvantage of cinchonine is, that the cinchonine tungstate takes longer to settle out than the mercurous tungstate. The base cinchonine is a bulky white powder, and only slightly soluble in water, but dissolves readily in dilute HCl. A convenient strength of solution is 5 %, and is made up by weighing out the base, treating with water, and adding the minimum amount of HCl to effect solution. It keeps indefinitely, and 5 cc. is sufficient to precipitate WO_3 in quantities up to 100 mg. The cinchonine serves to throw out the whole of the tungstic acid from the acid liquors of the assay, and so counteracts the weakness in this respect of the various acid methods. The most suitable conditions for the precipitation of cinchonine tungstate from solutions of alkali bases are, in a minimum of acidity, a bulk of 100 to 200 cc., warm solution, standing overnight if possible. The precipitate should be washed with a weak solution of cinchonine. This last is an important point, otherwise small amounts of cinchonine tungstate would be carried through the filter by a water-wash. Where a number of assays are to be made they could be brought to the precipitation stage in the late afternoon and completed the following morning.

Having selected the methods considered most suitable for the type of ore and product under consideration, samples of feed and tailings were taken for the experimental work. The feed assayed about 0.9 % WO_3, and the tailing about 0.27 % WO_3.

Mercury Method. The line of attack was commenced with the mercury method. This method is similar to the cinchonine methods

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* "The Uses of Cinchonine in the Assay of Tungsten Minerals," by H. W. Hutchin, I.M.M. Bulletin 164. May 30th, 1918.

(described at a later stage) up to the point of precipitation, where the solution is neutralized with nitric acid instead of hydrochloric acid. The precipitation is carried out in a strictly neutral solution with mercurous nitrate. The results on a sample of tailings were anything but concordant. With a sodium-peroxide fusion a result* of 0.37 % WO_3 was obtained, and digestion with caustic soda gave results of 0.038 % WO_3 and 0.048 % WO_3 respectively.

A sample of 2 grm. of feed was then fused with sodium-peroxide in a nickel crucible, and gave a result of 0.73 % WO_3. With the exception of the first result, which was not corrected for SiO_2, these assays by subsequent work were shown to be low.

CINCHONINE METHODS.

Acid Attack.—The method used was as follows:—5 grm. charge, finely powdered, boiled down with 50 cc. str. HCl to about 5 cc., a few drops HNO_3 added, and digested for five to ten minutes longer. Dilute to 100 cc., raise to boiling, nearly neutralize with caustic soda solution (25 %) and an excess of 20 cc. finally added. Solution boiled for a few minutes, cooled, transferred to a 250 cc. flask, volume adjusted to 250 mark, allowed to settle, and 200 cc. filtered off. To filtered portion added HCl till just acid, then 5 cc. cinchonine solution, warmed and stirred well, finally allowed to stand a few hours or overnight, filter, wash with dilute cinchonine solution, ignite, and weigh as WO_3. A sample of 5 grm. of tailings by this method gave 0.288 % impure WO_3, and on correcting for SiO_2 with HF gave 0.268 % WO_3.

A further sample of 10 grm. of tailings was taken, and the solution bulked up to 500 cc. 250 cc. of the clear solution was syphoned off and precipitated, giving impure WO_3 as 0.308 %. Correcting this for SiO_2 gave a value of 0.272 % WO_3. The other half of the solution was filtered and precipitated, giving impure WO_3 as 0.316 %, which, on correction for SiO_2, gave a result of 0.272 % WO_3.

Modification A.—A further 10 grm. of tailings was treated, using less acid for the attack, in order to conserve time. The results in this case, by halving the solution, gave 0.260 % WO_3 and 0.256 % WO_3 respectively, rather pointing to an incomplete attack.

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* Not corrected for SiO_2.

Modification B.—The method was again somewhat modified by treating a 10 grm. charge of tailings with 40 cc. HCl and finally evaporating to about 3 cc. with the addition of HNO_3. The residue was then digested with 20 cc. of (25 %) NaOH for 10 minutes, diluted with water, and filtered. The solution was bulked to 400 cc. and two (200 cc.) portions precipitated with cinchonine. The results after correction were 0.22 % WO_3 and 0.248 % WO_3, which, in the light of subsequent work, were unsatisfactory.

DIGESTION WITH CAUSTIC ALKALI.

With this method the charge may be as high as 12.5 grm., which is a considerable advantage in the case of low residues.

Method.—The ore is digested in a 4-in. dish with 20 cc. caustic soda (25 %) on a water bath for 40 minutes, diluted with very weak soda solution, transferred to a 250 cc. flask, and the volume adjusted to 250 cc. 200 cc. of a filtered portion is just acidified with HCl, 5 cc. cinchonine solution added, warmed, allowed to stand, etc.

A 5-grm. charge of the tailing was treated by this method and gave a value after correction for SiO_2 of 0.256 % WO_3.

Modification C.—A further amount of 12.5 grm. of tailings was digested for one hour with 20 cc. of caustic soda (25 %). The whole was then partially neutralized with HCl and filtered. The filtrate was evaporated to 100 cc., made just acid with HCl, and precipitated by the addition of 5 % cinchonine solution. After warming and stirring it was allowed to stand overnight, filtered cold, washed with weak cinchonine, and weighed ; this gave a result of 0.256 % WO_3.

These figures seemed on the low side, possibly due to incomplete attack. In order to test this point a sample of 3 grm. of feed was taken and digested as in the original method and filtered. The residue was reserved for further treatment. The WO_3 was precipitated with cinchonine, and gave a value of 0.803 % WO_3 after correction for SiO_2. The residue from the digestion was then dried, incinerated, and fused with sodium peroxide in a nickel crucible, the fusion dissolved in water, etc., and precipitated with cinchonine. An additional precipitate of WO_3 was obtained, amounting to 0.116 %, giving a total of 0.919 % WO_3. It was evident from this that the attack by caustic soda was incomplete. To achieve successful results by this method fine grinding is essential. With ore and residues this may be carried out in a Wedgwood mortar. A sample of 10 grm. can be sufficiently reduced in 20 minutes in a 9-in. mortar.

ATTACK BY FUSION.

The charge in the case of this method is necessarily limited, but it can be relied on to bring all the WO_3 into solution. The most satisfactory fusion was obtained with sodium peroxide in nickel crucibles.

Method.—The finely-powdered ore is intimately mixed with four times its weight of sodium peroxide in a nickel crucible and fused for about 30 minutes. The fusion is poured on to a porcelain tile, and, when cool, placed, together with the crucible, in a beaker, and the melt dissolved out with water. Filter and wash well with water. The filtrate contains WO_3 in solution, together with MoO_3, Al_2O_3, phosphates, etc. Make slightly acid with HCl, add a few drops of NH_4OH to precipitate Group III. metals. Filter and wash with hot water. Make filtrate just acid with HCl, add 10 cc. cinchonine solution, warm, and stir, and allow to stand for 2 hours or over-night. Filter cold, washing with 0.1 % cinchonine solution. Should any cloudiness appear in filtrate it must be re-filtered. An 8-cm. ashless filter paper is used. The precipitate is dried, ignited at red heat, and weighed as WO_3, which should be a bright canary-yellow. With a charge of 5 grm. of tailings, the percentage of WO_3, after correction for SiO_2, was 0.28 %.

A further assay was run on 12.5 grm. of tailings, fused in successive portions. After solution of the melt in water the liquid was transferred to a 500 cc. cylinder and bulked up to 500 cc. 200 cc. of the clear liquid was taken off by pipette, acidified with HCl, and excess ammonium hydrate added. The solution was filtered and precipitated as before, and the resulting WO_3, after correction, was 0.28 %.

The residue from this fusion was digested with 20 cc. of a (25 %) NaOH solution for 45 minutes, and treated as in the soda digestion method for WO_3. There was no precipitate with cinchonine, so the extraction was evidently complete.

VOLUMETRIC METHODS.

A volumetric method which would replace the long and tedious gravimetric methods, and at the same time be accurate, would be very welcome. G. M. Enos,* in introducing his method, mentions the fact "that even a skilled analyst cannot complete an analysis by some gravimetric methods in less than ten to fifteen hours."

Enos's Method.—The outline of Enos's proposed volumetric method is as follows:—It consists in acidifying a solution of an alkaline tungstate with sulphuric acid, and the reduction of the tungsten from the hexavalent to the tetravalent state in acid solution by means of a Jones reductor, and finally oxidizing the tungsten to the hexavalent condition with a standard solution of potassium permanganate.

The results tabulated with this method appear promising, but the lowest grade of ore treated by Enos was a tungsten sand carrying 2.8 % WO_3. Several attempts were made to apply this method to the King Island tailings, but without success. Evidently it is a method more adapted for a higher grade ore.

Further experiments were carried out with a view to shortening the time required for the estimation and at the same time avoiding the final gravimetric estimation, with its liability to manipulation losses.

New Volumetric Method.—The following volumetric method was eventually evolved. In outline it is as follows:—The WO_3 is obtained in solution either by soda digestion or alkali fusion, and precipitated by means of cinchonine. The precipitate of cinchonine tungstate is dissolved in ammonium acetate, to which is added a definite volume of lead acetate of known strength, in excess of that required to react with the ammonium tungstate. The excess lead acetate is then titrated with a standard solution of ammonium molybdate, and from the amount of lead acetate consumed the WO_3 is calculated.

The detail is as follows: For tailings the soda digestion attack would be best, as a larger charge could be taken. For feed and ore the peroxide fusion would be suitable. Whichever method of attack is followed, the WO_3 is obtained in solution as an alkaloid tungstate, and the following reactions are involved:—

$$(a)\quad \underset{\text{Tungstate}}{\underset{\text{Calcium}}{CaWO_4}} \ \overset{}{\text{and}}\ + \ \underset{\text{hydrate}}{\underset{\text{sodium}}{2NaHO}} \ \text{give}\ = \ \underset{\text{hydrate}}{\underset{\text{calcium}}{Ca(HO)_2}} \ \text{and}\ + \ \underset{\text{tungstate.}}{\underset{\text{sodium}}{Na_2WO_4}}.$$

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* *Mining and Scientific Press*, June 12, 1920 (abstract from *Pahasapa Quarterly*).

(*b*) $Na_2WO_4 + (C_{19}H_{22}N_2O)_2 2HCl = 2NaCl + (C_{19}H_{22}N_2O)_2 H_2WO_4$.

Sodium Tungstate and cinchonine give sodium chloride and cinchonine tungstate.

(*c*) $(C_{19}H_{22}N_2O)_2H_2WO_4 + 2(NH_4)C_2H_3O_2 = (C_{19}H_{22}N_2O)_2 (HC_2H_3O_2)_2 + (NH_4)_2WO_4$.

Cinchonine Tungstate and ammonium acetate give cinchonine acetate and ammonium tungstate.

(*d*) $(NH_4)_2WO_4 + Pb(C_2H_3O_2)_2 = {}_2(NH_4)C_2H_3O_2 + PbWO_4$.

Ammonium Tungstate and lead acetate give ammonium acetate and lead tungstate.

(*e*) $Pb(C_2H_3O_2)_2 + (NH_4)_2MoO_4 = PbMoO_4 + {}_2NH_4C_2H_3O_2$.

Lead Acetate and ammonium molybdate give lead molybdate and ammonium acetate.

The precipitate of cinchonine tungstate, after thorough washing, is placed, together with the filter paper, in the beaker used for the precipitation, and covered with 10 cc. ammonium acetate. After boiling for a few minutes to effect solution, 20 cc. of $\frac{N}{10}$ lead acetate is added to precipitate the tungsten as lead tungstate. Allow to stand on hot plate for half an hour, and titrate the excess of lead acetate with a standard solution of ammonium molybdate.

It will be noticed in the following experiments that a standard solution of ammonium molybdate, approximating to a 1 % solution, is used. This solution happened to be made up, but a solution of about half that strength would be better. This would double the burette reading and minimize the chance of error. By using this method considerable time, otherwise spent in manipulation, is saved. The precipitate of cinchonine tungstate has not to be ignited and weighed, nor corrected for SiO_2, and the re-fusion of the WO_3 for the removal of Group III. bases is also avoided.

Solutions Required.

Ammonium Acetate.—Equal volumes of water, ammonium hydrate, and glacial acetic acid, well mixed and made slightly alkaline.

Lead Acetate.—16.125 grm. per litre.

Ammonium Molybdate.—8.7 grm. per litre.

Example.—

20 cc. $Pb(C_2H_3O_2)_2 = 21.9$ cc. $(NH_4)_2MoO_4$.

$\therefore$ 1 cc. $(NH_4)_2MoO_4 = 0.00989$ grm. lead.

$\therefore$ 20 cc. $Pb(C_2H_3O_2)_2$ added to assay $21.9 \times 0.00989 = .216591$ grm. Pb.

and excess titrated with $(NH_4)_2MoO_4 = 20.8 \times 0.00989 = .205712$ grm. Pb. The difference $0.216591 - 0.205712 = 0.010879$ grm. Pb consumed by WO_3.

207 parts lead = 232 parts WO_3.

$$\therefore \frac{0.010879}{1} \times \frac{232}{207} \times \frac{100}{1} \times \frac{1}{5} = 0.243\ \%\ WO_3.$$

Precautions for Running the Assay.

1. Necessity for very fine grinding.
2. Thorough washing of residue.
3. Keeping solution low in bulk to avoid evaporations.
4. Any elements which react with lead acetate must be removed—*e.g.*, molybdenum.

Two grm. of the feed were treated by this method, using the soda digestion attack and filtering the whole of the assay, instead of bulking up and taking an aliquot part, as in the tailings assay. The amount of WO_3 obtained was 0.81 %.

Convenient bulks to make assay up to before taking an aliquot part are the following:—

12.5	grm. ore	dilute to	500 cc.
10.0	,,	,,	400 ,,
6.25	,,	,,	250 ,,
5.00	,,	,,	200 ,,

In each case take 200 cc. of a filtered portion. This will be equivalent to 5 grm. ore.

Further assays were run on the feed by this method, using the sodium peroxide fusion in nickel crucible. Two grm. of ore were taken in each case, and gave respectively 0.88 % WO_3 and 0.94 % WO_3.

Comparison of results of the fusion with those by the soda digestion method rather points to an incomplete attack by the caustic soda.

This difference is also accentuated by the presence of a small amount of molybdenite in the ore, amounting to 0.007 % molybdenum. In the soda digestion attack this would only be partially dissolved, whilst with the alkali fusion the whole of it would go into solution. The molybdenum would then be precipitated as cinchonine molybdate, which would in turn combine with the lead acetate, leaving a smaller excess to be titrated by ammonium molybdate. The final result would thus be too high. This point was demonstrated by adding 0.02 grm. molybdenite to a 2-grm. assay of the feed and running it in conjunction with a similar assay without the addition of molybdenite. The consumption of $(NH_4)_2MoO_4$ in the first instance was 14.8 cc., whilst in the second case, without adding molybdenite, it was 17.9 cc.

The same thing occurs in the gravimetric estimation in the presence of molybdenum—high results are obtained. In the case of the feed under consideration, the amount of Mo present is small (.007 %), but where ores containing larger quantities are to be assayed this volumetric method could only be applied after removal of the molybdenum. This might be done in the combined cinchonine precipitate by re-solution and precipitation of molybdenum by H_2S.

In the case of the gravimetric estimation, the final precipitate of WO_3 is fused in a platinum crucible with Na_2CO_3 or $KHSO_4$, dissolved in water, tartaric acid added, and the molybdenum precipitated as MoS_2 by H_2S, ignited to MoO_3, and weighed, this weight being deducted from the WO_3.

Other volumetric methods were attempted, based on the solubility of WO_3 in caustic soda and alcoholic potash, but the results were not sufficiently encouraging to proceed with them.

COLORIMETRIC METHODS.

Attention was now turned to colorimetric methods, as many of the elements are successfully estimated by these means, even when present in very small quantities. In the method employed for the detection of the presence of tungsten in ores, given in an earlier section of the paper, zinc or tin is added to the hydrochloric acid solution of the ore. In the presence of tungsten a blue colour is obtained. An attempt was made to apply this reaction in the following procedure :—A solution of stannous chloride was prepared by dissolving 20 grm. of tin in HCl and diluting to 100 cc. 0.01 grm. of pure WO_3 was dissolved in sodium hydrate (20 %) and acidified with HCl.

5 cc. of the above $SnCl_2$ solution was then added, and a distinct blue colour was imparted to the solution. This colour was permanent for some time, even in the cold.

This method was now applied to the ore. A charge of 4 grm. was taken, digested with 20 cc. of 25 % NaHO, filtered, and the WO_3 precipitated with cinchonine. The cinchonine tungstate was then dissolved in freshly-prepared ammonium-chloride solution (made from NH_4HO and HCl). 10 cc. of the $SnCl_2$ solution was added, and a bluish-violet colour was imparted to the solution.

A standard solution was prepared from 0.01 grm. of pure WO_3, using the same method of reduction with $SnCl_2$.

Owing to the violet tinge in the assay it was found difficult to get an accurate comparison, but the result accepted gave a percentage of 0.75 % WO_3.

A further estimation by the same method gave a value of 0.93 % WO_3 in the ore.

Taking 3 grm. of the ore, by the same method a value of 0.99 % WO_3 was obtained.

Further estimations on 2 grm. of feed, by varying the mode of attack, gave the following results :—

No. 1, fused with Na_2O_2 in a nickel crucible.

No. 2, digestion with NaHO.

No. 1 gave a result of 1.10 % WO_3 and No. 2 1.16 % WO_3.

A further modification was tried by igniting the cinchonine tungstate to WO_3, dissolving the WO_3 in NaHO, and reducing as before. This only served to intensify the violet tinge in the blue solution.

From experiments with a solution containing molybdenum, it was found that a similar violet colour was obtained. Even with the small percentage of molybdenum in the ore (0.007 %) this method is not sufficiently reliable. A method is being investigated by which the molybdenum is first removed by means of H_2S, and which will not require the preliminary precipitation of the tungsten. The method so far promises every success.

TABLE OF RESULTS OBTAINED BY VARIOUS METHODS.

The amounts shown herein represent percentages of WO_3.

Sample.	Aqua Regia method.	Mercury method.	CINCHONINE METHODS.			Colori-metric method.	New Volu-metric method.	Remarks.
			Acid attack.	Soda digestion.	Na_2O_2 fusion.			
King Island *Feed* to Mill.		0.73 (*e*)		0.803 (*b*) 0.116 0.919 total (*h*)	0.94	0.75 (*f*) 0.93 (*f*) 0.99 (*f*) 1.10 (*e*) 1.16 (*f*)	0.81 0.88 0.94	(*b*) Residue from first attack, re-treated by fusion. WO_3 recovered = 0.116 %. (*e*) Na_2O_2 fusion. (*f*) Soda digestion attack. (*h*) The final WO_3 was fused with Na_2CO_3 and re-precipitated with cinchonine.
Tailings from Mill, King Island.	0.244 (*a*) 0.028 0.272 total	0.37 (*d*)	0.272 0.272 0.268 0.260 0.256 0.220 0.248	0.256 0.256 0.272	0.279 (*e*) 0.280 (*c*)		0.243 0.243	(*a*) 0.028 % WO_3 in addition recovered by cinchonine from acid liquors. (*c*) Residue digested with caustic soda found to be free from WO_3. (*d*) Not corrected for SiO_2.

EFFECT OF IMPURITIES IN THE ORE.

In an analysis of the King Island ore the chief interfering elements were found to be arsenic (0.046 %) and molybdenum (0.007 %). Phosphorus is at present being investigated.

The incidence of molybdenum both in the gravimetric and volumetric methods has already been discussed.

The presence of 0.046 % of arsenic requires consideration, although H. W. Hutchin, in his work previously mentioned, states:—"For the assay of poorer products with more pronounced impurities of arsenic and fluorspar, cinchonine is invaluable. Arsenic and phosphorus cease to be disturbing factors."

A preliminary calcination, however, should eliminate the arsenic, but further work requires to be done on this point. With regard to phosphorus, in the cinchonine methods, whether by acid or alkali attack, the phosphorus would be eliminated, and without effect.

There is a tendency on the part of cinchonine to carry down small amounts of the Group III. bases, resulting from an incomplete precipitation of this group.

To guard against this liability to error, it is necessary to fuse the final WO_3 residue with six times its weight of pure Na_2CO_3 in a platinum crucible, dissolve the fusion in water, filter off any impurities, make acid with HCl, and re-precipitate the WO_3 with cinchonine, ignite, correct for SiO_2 by H_2SO_4 and HF, ignite. and weigh until constant.

SUMMARY AND CONCLUSIONS.

The weakness of the purely acid methods, especially for low-grade ores, is evident, owing to the incomplete precipitation of the WO_3 below a certain concentration.

The selection of a suitable method is governed by (*a*) the grade of material under consideration, and (*b*) the amount of interfering elements revealed by an analysis.

Concordant results would hardly be expected by taking less than a 5-grm. charge for material under 0.5 % WO_3. Cinchonine has been found to be superior to mercurous nitrate as a precipitant for WO_3 on impure and low-grade ores. The best conditions for the precipitation of cinchonine tungstate are from solutions of low acidity, a bulk of about 150 cc., standing several hours, preferably overnight

The precipitate must be washed with a weak cinchonine solution. Molybdenum is precipitated under these conditions, and must be separated from the final precipitate of WO_3, or removed prior to precipitation.

The silica should always be removed from the final WO_3 by volatilization with one or two drops of H_2SO_4 and a few drops of HF. The HF, as ordinarily sold, is quite unsuitable for this purpose owing to the impurities it contains. Baker's re-distilled and analysed product is suitable and available.

The final WO_3 should always be fused with Na_2CO_3, the impurities removed, and the WO_3 re-precipitated with cinchonine, ignited, and weighed until constant.

A number of methods which have appeared in recent years have been investigated, but, whilst highly suitable for the purpose for which they were designed—*i.e.*, high-grade ore and concentrate—could not be successfully applied to low-grade residues such as those of King Island. The only safe method for these residues is the alkali fusion in nickel crucibles, followed by cinchonine precipitation, removal of molybdenum, if necessary, from the final WO_3, correction for SiO_2 by hydrofluoric acid, and removal of iron, alumina, etc., from the WO_3 by fusion with Na_2CO_3, and re-precipitation with cinchonine. This method is embodied in the paper. Where accuracy must be sacrificed to time, then a soda digestion attack would permit of a larger charge (up to 10 or 12 grm.), followed by cinchonine precipitation and the new volumetric method.

By this means a considerable amount of time would be saved and reasonable accuracy attained.

In conclusion, the author is indebted to Mr. F. Voss Smith, general manager, Block 14 mine, and Mr. L. Venn Brown, manager, King Island scheelite mine, for facilities afforded in the preparation of this paper, and to Messrs. W. Hobbs and R. B. Oliver for able assistance in the analytical work.

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VENTILATING METALLIFEROUS MINES: A METHOD OF ATTACK.

By THOS. G. HANTON, B.E. (Member).

(*Read before Broken Hill Branch, 25th May*, 1920.)

THERE is available a considerable amount of literature concerning the practice, and, to a smaller extent, the theory of ventilation as it applies to coal mines. Publications considering the subject of ventilation of metal mines from a practical viewpoint are much less numerous, whilst the treatment of the theoretical aspect of the question (except in so far as is common to coal mining) appears to have been almost neglected.

This may be due to one of two causes—

(*a*) That in many metal mines (especially those which have not attained a great depth), on account of the greater number of connections with the surface, as compared with coal mines, natural ventilation has sufficed.

(*b*) That in metal mines where the foregoing is not the case the solution of the ventilation problem from theoretical considerations has been regarded as involving so many complications that any attempt at the determination of a set of concrete ventilation figures applying to and throughout the mine would be futile.

Whilst it is freely admitted that the difficulties inherent in the application of theory to the ventilation of metal mines are numerous, it must also be admitted that few attempts have been made to overcome them. The ultimate aim, of course, would be the collection of sufficient data to enable the probable behaviour of the air-currents throughout the whole of the workings of any mine to be accurately predicted under any particular set of circumstances. Failing the attainment of this goal of perfection, it would at least appear that much valuable information might be obtained. In ventilation, as in

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This paper is separately bound, and may be, if so desired, detached complete from this number.

all other subjects, it seems imperative that development shall be along sound theoretical lines if any marked progress is ever to be made.

This paper presents a method of attack which has been commenced, and is still in progress, at the mining department of the Zinc Corporation Ltd., Broken Hill, N.S.W. Nothing in the nature of a general comprehensive account of mine ventilation is attempted in the paper, nor is any consideration given to artificial means of ventilation, these not being available at the time. No results can yet be published, as the work undertaken to carry out the improvements suggested by this investigation are not yet complete.

A short description of the features of the mine, in so far as they may affect the question of ventilation, will not only show the conditions under which the investigations were conducted, but may also help to explain the objects of their various phases.

The ore-body at the Zinc Corporation is continuous over its length, following along a main eastern wall and splitting into an eastern and western ore-body at the north end of the mine. The width of ore exploited varies from 6 ft. to a maximum of over 100 ft. The main hauling shaft is situated in the foot-wall country in a position almost central to the length of the ore-body. Practically all the ore is broken in open stopes. The stopes are served by a system of mullock-passes extending from the surface throughout the vertical extent of the underground workings. The average horizontal interval between these is 130 ft. in the southern end of the mine, and 100 ft. in the northern end. As far as the subject of this paper is concerned, the system of exploitation underground in general may be regarded as that necessary and desirable for an ore-body of the above size.

The main air-supply of the mine is drawn through a vertical, close-timbered, three-compartment shaft situated at the southern end of the workings. Four of the levels from the main shaft—Nos. 4, 6, 7, and 8 have direct connection to this downcast shaft, the other levels have only indirect connection. The upcast air passes through various openings in the extreme northern end of the mine, reaching the surface through two or three old shafts connected to the higher levels. Many of the openings have been constructed solely for the purpose of air-ways, and the extent of these is being systematically increased. Under working conditions the flow of air is materially increased artificially by means of a fan operating at the top of one of the old shafts mentioned—No. 4 shaft—which then forms the main upcast for the mine. At the time of cessation of operations, due to the strike of workmen, the fan had been temporarily removed to an adjacent old shaft—No. 3—whilst stripping operations were in progress in the No. 4 shaft, for the purpose of increasing its air-carrying capacity. The material broken from the stripping completely blocked the passage of air in this shaft. From somewhat similar causes other portions of the upcast were also impeded. Thus the investigations were carried out under conditions of abnormally restricted upcast, but this condition is not considered as having adversely affected the general conclusions arrived at.

Measurement of Air-Currents.

For the measurement of air-currents exceeding 100 ft. per min. anemometers of the windmill type were used. Three of these instruments were employed, two of which were exclusively used underground, and the third kept in the office for purposes of standardization. Before any measurements were taken underground a series of readings was obtained with the three instruments running together. The results obtained showed that for velocities of less than 100 ft. per min. all three were unreliable. For air velocities ranging from 100 ft. to 300 ft. per min. a correction of 30 ft. per min., to be added to the observed reading, was found necessary for one anemometer (a Stanley), whilst for those exceeding 300 ft. per min. no correction was needed. For the other two (one a Kew standardized and the other of unknown make) a correction derived from the Kew correction graph appeared suitable.

For readings of air velocities in shafts and in the majority of winzes the anemometers were used attached to the end of an iron rod 5 ft. in length, and were lowered into the opening the full extent of the rod. Five seconds were allowed for withdrawing the rod to the top and clamping the instrument. In all readings the observer kept clear and did not obstruct the air-current. The period over which the reading was taken was in almost every instance 1 minute. Intervals of 2 and 3 minutes were tried, but the velocities obtained in every case corresponded so closely with those of the 1 minute readings that the latter time was adopted throughout. As all readings taken were comparative, they were invariably taken at corresponding spots in the various air-ways and at the same spot in each particular one. Moving the anemometer over the air-way whilst the reading was being taken was considered very likely to introduce error, due to eddy currents.

For the measurement of air-currents which were either too slow to move the anemometer or to ensure a reliable reading if it did move the following method was employed :—The direction of the current having been ascertained, a measured distance along the air-way was set out. A piece of fuse, 4 to 6 in. in length, was lit at the inlet end of the distance, and the time taken by the powder smoke to travel the measured distance noted by an observer at the other end. Thus the velocity of the air was obtained. For estimating the quantity in cubic feet per minute the average cross-sectional area over the measured distance was used. Thirty feet was found to be a suitable average distance for fuse measurement. For extremely slow motion 15 ft. was used. as there was a tendency for the smoke fumes to become dissipated before the full 30 ft. was covered. Time was noted from the instant of spitting of the fuse. By slightly splitting the fuse before applying the light, spitting is practically instantaneous. If spitting is slow, a certain amount of smoke arises first from the tape, which may be somewhat troublesome for correct timing.

This method was used in default of any better one available, no instrument apparently having been devised for the purpose of measuring very slowly moving air-currents. In all instances it proved satisfactory—much more so than would be imagined from a casual consideration of it.

The hygrometers used were of the ordinary type, consisting of a wet and dry-bulb thermometer of similar construction, mounted side by side on a frame. A series of readings was first made with these and the engineering office thermometer and a correction determined, taking the latter as standard, applied to all readings taken. The usual method of taking wet-bulb temperatures was found to be inaccurate : so in actual practice, before the reading was made, the thermometers were swung at the rate of 15 ft. per second, the observer standing sideways to the air-current. This ensures a minimum wet-bulb reading, the difference between this and a stationary reading depending on the degree of saturation of the air, amounting to a reduction of 1½° in some instances noted. Whirling and reading are repeated several times to ensure that the lowest reading of the wet bulb has been obtained.

The pressure of air was measured with an aneroid barometer with mercury scale only. A comparison was made with the engineering office mercury barometer, the two being placed side by side and simultaneous readings of each taken at half-hour intervals over a period of 3½ days. Thus the necessary correction to be applied to the aneroid to reduce its readings to equivalent mercury barometer readings was obtained. Otherwise, it is apparent that no standard to which the varying atmospheric conditions could have been referred would have been available.

Whilst aneroid readings were being made during the actual ventilation work the mercury barometer was read each half hour. All the mercury-barometer readings were corrected to inches of mercury at 32° F. Thus, a correction to be applied to the aneroid for diurnal variation, in addition to the constant correction above, was derived. For any complete section of the test aneroid readings were reduced to one specific surface reading in accordance with the above data. The comparative surface reading taken was one in which the aneroid, with the constant correction applied, corresponded with the mercury barometer corrected to 32° F. In all instances the aneroid, before the reading was made, was given time to come to rest, and tapped gently when placed in position. It was used encased in a wooden box to prevent any variations due to the heat of the body or excessive vibration. For accurate results, especially in this work, it seems essential that all possible precautions should be taken to ensure that proper corrections are applied to the barometer readings.

A water-gauge of the usual type, consisting of an open U-shaped glass tube partially filled with water, with a vertical scale attached between the legs, was also employed for measuring ventilating pressure in the mine.

METHOD OF ATTACK.

The general scheme consisted of the measurements of air-currents and temperatures in all drives and stopes, and the determination of the pressure of the air wherever necessary for the calculation of the motive columns required. As only two anemometers were available for underground use, and only two hygrometers, only two parties could be employed; thus, it was not possible to take more than two sets of simultaneous readings. To obtain comparative results differences due to diurnal variation were eliminated as far as possible by the organization of the readings. From these results the forces producing air-currents were calculated and equated with the measured air-currents to determine coefficient factors. In this scheme the mine was separated into districts, each level being taken as a separate district.

MOTIVE COLUMN OR THE FORCE PRODUCING AIR-CURRENT.

For the calculation of the motive column of air in mines various methods are described in ventilation works. In most of these the moisture contents of air are neglected. In "The Ventilation of Mines," by Johann Sarvaas, only the weight of dry air in upcast and downcast is taken into account. Redmayne gives various methods, all of which assume the air to be pure and dry. One formula given by him is—

$$M = D \frac{T - T_1}{T + 459}$$

where M = motive column (expressed in height of air column,.

D = depth of upcast shaft.

T = temperature of upcast.

T_1 = temperature of downcast.

In this formula, in addition to neglecting the weight of water vapour, the barometric pressures are also ignored. In other methods of calculation Redmayne does not state definitely the pressures which should be used. Sarvaas is likewise not very clear upon the same point. Others, again, appear to use an average barometric pressure, as between upcast and downcast, but do not make this very plain.

Considering the matter from the viewpoint of purely physical reasoning, however, it would appear that the only way to calculate the amount of motive column with the greatest possible accuracy is from the actual weights of air in the upcast and downcast columns. The differences in weight per cubic foot of the downcast and upcast air, multiplied by the height of the upcast, will equal the motive column. The actual size of upcast or downcast opening in no way affects the calculation of the motive column. If the weights of air are expressed in pounds, and the depth of the upcast in feet, the resultant motive column will be in pounds per sq. ft. The weight of a cubic foot of moist air may be determined as follows:—

$$W = \frac{1.3258\ (B - b)}{459 + t} + \frac{0.826\ b}{459 + t}$$

where W = weight of 1 cub. ft. of moist air in pounds.
B = barometer reading; inches of mercury.
b = barometric pressure expressed in inches of mercury supported by the vapour of saturation (obtained from tables of tension of aqueous vapour).
459 + t = absolute temperature in degrees F., t being the dry-bulb reading.

The figure 0.826 is obtained from the product of 1.3258 × 0.623, 0.623 being the density of water vapour, taking air as unity. The first portion of the equation is derived thus:—Considering dry air, if the volume at 0° F. = 1, then the volume at any temperature, t, the pressure remaining constant, is $1 + \frac{t}{459}$. The weight of 1 cub. ft. of dry air at a temperature of 0° F. and a pressure of 1 in. of mercury = .0028885 lb.

$$\text{so } 1 : 1 + \frac{t}{459} :: W : .0028885.$$

As the volume, and consequently the weight also, varies directly according to pressure, when this variation is also taken into account, the formula for dry air becomes—

$$W = \frac{1.3258 \times B}{459 + t}$$

1.3258 being the weight of 459 cub. ft. of air at 0° F. and 1 in. of mercury.

For pressures, in the calculations of motive columns, the mean value of the corrected aneroid reading on the surface at the top of the upcast or downcast and the corresponding reading at the bottom of the upcast or downcast respectively was used. In some of the later calculations, for greater accuracy, the geometric mean, including the various intermediate readings, was used.

The temperatures used in the calculations were, in all cases, the geometric mean of the various readings throughout either upcast or downcast, the mean of the wet and of the dry-bulb readings, each, of course, being determined. The vapour pressure, b, for this mean wet-bulb reading was employed.

With regard to temperatures, it was found that the temperatures in the downcast shaft near the surface were considerably lower than the prevailing surface temperatures, and that a steady temperature was not registered until a depth of at least about 100 ft. had been reached. A series of temperature readings were taken to determine the point at which this occurred. The upcast temperature appears to be remarkably constant, regardless of surface conditions, and the upcast air is in almost every case saturated when it reaches the surface. A series of readings under varying surface conditions was taken to establish these points. It seems most important that all temperatures should be taken actually in the places to which they refer —*e.g.*, a downcast temperature should be taken in the downcast shaft, and not in the adjoining plat. A consideration of the formula from which the weight of air, and thus the motive column, are derived will show the necessity for the determination of barometric pressures as accurately as possible.

As, on some levels (fig. 1), the plat sill at the downcast end of the level is not quite as deep as the upcast, in calculating the motive column for these levels the difference in the weight of the air was multiplied by a figure representing the depth of the downcast shaft below the level of the top of the upcast. To this motive column was added the figure obtained by multiplying the difference in the weights of the air along its passage to the upcast outlet and the weight at the upcast outlet by the extra depth of the upcast shaft. Conversely, where the bottom of the upcast shaft was shallower (fig. 2), the amount

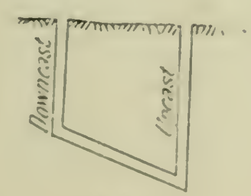

FIG. 1.

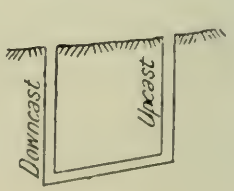

FIG. 2.

added was the difference between the weights of air at the bottom of the downcast and along the passages to the upcast multiplied by the difference in level of the bottom of the shaft. These differences in level are due to the grading of drives and gangways for ease in trucking.

Peele's handbook expresses the equation for the weight of moist air in slightly different terms to that given in the foregoing, the form in which it is set out in Peele being :—

$$W = \frac{1.3232}{459 + t} \times (H - 0.378\ p\ f)$$

where W = weight in lb. per cub. ft.
H = barometric pressure in inches of mercury.
f = pressure of saturated aqueous vapour, corresponding to temperature t.
p = percentage of saturation of the air divided by 100.

For dry air p = zero. This formula assumes that the density of aqueous vapour is 0.622 when air is unity. It is really a matter of personal preference as to whether this or the first formula quoted is used, as the only variation is in the form in which they are expressed. It must be borne in mind that the motive column is liable to variation with every change of temperature and surface conditions, being greater in the cooler portions of the day, and reaching a maximum in the winter months. An average value at the time of the test for the motive column acting on the portion of the mine then open was about 2 lb. per sq. ft., or about 0.4 in. water gauge.

FRICTIONAL RESISTANCE.

The coefficient of friction has been defined as being equal to the ventilating pressure required to overcome the resistance that a unit of air, moving with unit velocity, would meet with in circulating round a mine of unit-rubbing surface.

Various and very diverse estimations of this coefficient of friction K, are given by different authorities. The figure is expressed in various terms—feet of air column, inches of water gauge, and lb. per sq. ft. It is important to note also whether the value corresponds to a velocity expressed in terms of feet per minute or thousands of feet per minute.

The following are various values for K in lb. per sq. ft., and all reduced to a velocity expressed in feet per minute :—

Atkinson	.0000000217	lb. per sq. ft.	
Lupton, Long Wall Coal mine ..	.00000000477	,,	,,
D. K. Clarke, Railway tunnels ..	.0000000228	,,	,,
T. L. Elwen, Straight air-ways of irregular section in coal ..	.000000003594	,,	,,
Timbered shafts and brattices ..	.000000003686	,,	,,
Various Victorian mines	.000000005	,,	,,
Devillez	.000000009672	,,	,,
Murgue, Unlined galleries	.000000004524 to .000000006396	,,	,,
Arched galleries	.00000000156 to .000000003224	,,	,,
Timbered galleries	.000000007644 to .000000012532	,,	,,

Johann Sarvaas, in an example which he works out, uses for shafts size 10 ft. by 4 ft. the coefficient .000000005, and for levels, crosscuts, and winzes .0000000217 (Atkinson's)—*i.e.*, 4.34 times as much as for shafts. The consensus of opinion is that Atkinson's coefficient is in most cases much too high, but some authorities recommend its use on the grounds that the error will be on the safe side, which contention, though possibly quite sound, is not very convincing.

The value of K, used in all the original calculations of frictional resistance of air-ways on the Zinc Corporation, and still adhered to (except in the case of shafts), is taken from the following table supplied in Peele's handbook :—

COEFFICIENTS OF FRICTION IN AIR-WAYS.

R =	0.5	1.0	2.0	3.0
$C \times 10^3$	Values for $K \times 10^8$			
0.20	0.213	0.165	0.127	0.109
0.40	0.427	0.329	0.254	0.219
0.60	0.640	0.494	0.381	0.328
0.80	0.854	0.658	0.509	0.437
1.00	1.067	0.823	0.636	0.546
1.20	1.281	0.987	0.763	0.656
1.40	1.494	1.152	0.890	0.765
1.60	1.707	1.316	1.017	0.874
1.80	1.921	1.481	1.144	0.983
2.00	2.134	1.646	1.272	1.092
2.20	2.348	1.810	1.399	1.202
2.40	2.562	1.975	1.526	1.311
2.60	2.775	2.140	1.653	1.421

The effect of the roughness of the air-way is taken into account under the heading $C \times 10^3$. The effect of the sectional area is accounted for under the columns for R, the mean radius of air-way—

$$R = \frac{\text{Area}}{\text{Perimeter}}$$

Peele states that, for stone arched headings, $C \times 10^3$ varies from 0.20 to 0.60.
for headings with bare rock walls, $C \times 10^3$ varies from 0.60 to 1.60.
for timbered headings, $C \times 10^3$ varies from 1.00 to 2.60.

Usual average for a whole mine, $C \times 10^3$ varies from 1.00 to 2.60. The above value for a whole mine allows for normal leakage between air-ways. The other values do not. The above values are based on a density for mine air of 0.0749 lb. per cub. ft. As the figures in this table take into account most of the variations affecting the friction in air-ways, their use seems preferable, in the absence of more information determined by experiment for any particular mine, to any of the much more general figures given elsewhere. These values were used without any density correction being applied, as the weight of air differed so little from that for which the table was compiled that the variation in the value of K on this account was negligible. The pressure required to overcome the frictional resistance in any given air-way is expressed thus :—

$$p = \frac{KsV_2}{a}$$

where p = pressure in lb. per sq. ft. to overcome friction.
K = coefficient of friction.
a = cross-sectional area of air-way in sq. ft.
V = velocity in ft. per minute.
s = rubbing surface (*i.e.*, perimeter × length of air-way).

Now, if Q be the quantity of air in cub. ft. per minute passing through the air-way,

$$Q = aV$$

$$\text{or } V = \frac{Q}{a} \text{ and } V^2 = \frac{Q^2}{a^2}$$

so the value for p in the above equation may be expressed thus :—

$$p = \frac{KsQ^2}{a^3}$$

In any given air-course the values of K, s, and a are constant. These being ascertained, the resistance of the air-way, p, may be expressed as a constant multiplied by Q^2. For a comparison of the frictional resistances of air-ways, the above form of expression was found very convenient, Q being the only variable. The length, cross-sectional area, and perimeter of the various air-ways throughout the mine were determined. From these dimensions and the frictional coefficient table given the resistance for these air-ways in terms of Q^2 were calculated and tabulated. The following set of figures obtained for a series of stopes above one level are supplied as an illustration :—

Length.	Perimeter.	Cross-sectional Area.	Resistance in terms of Q^2.
30	64	237.0	.0000000000079 Q^2
135	54.2	123.5	.0000000002141 Q^2
135	43.8	100.9	.0000000003647 Q^2
170	34.8	68.4	.0000000011691 Q^2
110	60.4	145.2	.0000000001300 Q^2
72	128.4	380.4	.00000000000037 Q^2
38	211.2	1007.0	.00000000000917 Q^2
53	64.2	142.0	.00000000000418 Q^2
36	135.8	399.1	.00000000007533 Q^2
79	59.2	161.3	.00000000006096 Q^2

or a total for the above series of stopes of .00000000203682 Q^2.

A consideration of the above will show, *inter alia*, after due allowance has been made for variation in resistance arising from differences in length, the comparatively great resistance of those portions of the stopes of smaller sectional area. Consequently, the importance of maintaining as large an open space as possible in the narrower stopes seems apparent if a maximum circulation of air throughout the stopes is to be secured—that is to say, that as far as may be consistent with safety and the progress of exploitation they should be left unfilled as much as possible, and that there should, when filled, be no narrow necks between the top of the sand filling and the face of the stope.

The resistance of the timbered drive (average size taken at 6 ft. x 7 ft. 6 in.) extending under the above series of stopes was .000000030222 Q^2. A comparison of this with the total resistance of the overlying stopes, .0000000020368 Q^2, that of the drives being about 15 times as great as the stopes over the same distance, shows fairly definitely that, viewed solely from the standpoint of relative difference in frictional resistance alone, there should be no difficulty in inducing the greater portion of the air entering any level to travel through the stopes in preference to the drives. Exactly the reverse, however, happened in every instance observed. In the case of the stopes just quoted the inlet end of the stopes was only the height of the sill timber above the level (approximately 10 ft.), so the question of the resistance of any air-way of comparatively small size conducting air from the level into the stope was eliminated. Undoubtedly, in many cases this is one of the factors in reducing the supply of air into the stopes, as the results of experiments carried out as between other levels and stopes went to show, but, as the stopes in question made apparent, not absolutely the controlling one.

An explanation of the preference of the air for the drives rather than for the stopes was sought in the relative differences of motive column acting on the drive and on the corresponding stopes. In every instance, however, in the various motive columns calculated, that, acting on the stopes above any level, taking the whole length of the stopes from downcast to upcast, was slightly greater than the motive column for the drive, the difference varying from .003 to .09 lb. per sq. ft.

It has already been stated that during the test each level was treated as a separate district, but it may be again mentioned here that, in order to prevent complications owing to short circuits, and also to obtain a definite comparison between various parts of the workings, each level, except for an inlet at the one end and outlet opening at the other end, was isolated from the level immediately above or below it, all the intermediate connections being covered.

In the series of stopes examined the central portion is in each case higher than either end. In the stopes, the resistance figures of which are given, the crown is 48 ft. higher than the inlet end and 36 ft. higher than the upcast end.

Considering now the portion of the stopes from the inlet end to the dome, it is evident that a certain amount of pressure over and above that necessary to overcome friction alone is required to raise the cold and heavy downcast air to the highest point of the stopes; also, this becomes heated by the time it reaches the top of the stopes, and its natural tendency is still to rise, so that pressure will also be necessary from the crown of the stope to the upcast to push the hotter air on that side downhill again.

For the stopes in question, the differences in the average weight of the air from the inlet to the crown and the average weight from the crown to the upcast was 0.000474 lb. per cub. ft. In another series of stopes the difference in weights was 0.000905 lb. per cub. ft. Upon opening two mullock passes from the central portion of the stope at its highest points to the level above the inlet air travelled up the stope to the nearest opening and upcasted, whilst upcast air travelled along the drive up into the stope and back in the reverse direction up the other opening. The quantity of air circulating in the stope showed a marked increase as soon as the openings were available.

This seems to be direct evidence in favour of the fact that the pressure required to force the hotter air downhill in the stope is one of the main reasons for the greater flow of air through the drives than the stopes. It is hoped that the results of further investigations will throw more light on this matter. With a fan in operation, the water-gauge in the mine will be increased considerably, and the difference in motive column of stopes and the corresponding drives thereby accentuated. At the present time the differences are so small that it is difficult to assign any definite value to the part played by motive columns in this connection. The effect of a freer upcast upon the air-current through the stopes still remains to be investigated when the necessary work for the construction of suitable stope upcasts has been completed.

In attempting to equate the motive column with the total resistance of the mine for the quantities of air in circulation, the resistance of the downcast shaft as obtained from the table of coefficients of friction in Peele was abnormally large. This was so pronounced that the pressure available for overcoming friction throughout the remaining portion of the mine-circuit appeared not nearly sufficient for that purpose. The fact that it was difficult to obtain an approximation to the amount of upcast resistance added a further complication. From a consideration of the question, taking various motive columns corresponding to various measured quantities of air entering the downcast shaft, the conclusion was reached that either the value of K assigned to each compartment of the shaft was too great or that some other factor was involved. The figure first used, $\frac{.828}{10^8}$, certainly appeared excessive in view of the fact that the shaft is vertical and close-timbered. The figure used by Johann Sarvaas for shafts—

i.e., .000000005 (which, he states, was the result of a few isolated experiments in Victorian mines)—was then tried, but did not reduce the total shaft-resistance to quite within the required limits.

As the results of experiments on various closed circuits in which the downcast resistance did not enter, it appeared that the values of the coefficients of friction for the levels and stopes, as derived from Peele, could reasonably be assumed as correct.

A tentative value of K for this downcast shaft was then determined thus:—A motive column was calculated from the actual pressures and temperatures prevailing at a given time, in this instance amounting to 2.468 lb. per sq. ft. The actual observed quantities of air circulating through the shaft and the levels corresponding to this motive column were known. The resistance of the mine-circuit (exclusive of downcast and upcast) was calculated for these measured quantities of air, using Peele's coefficients, the result obtained being 0.601 lb. per sq. ft. As the total motive column for the mine is equal to the total resistance of the mine-circuit, it follows, then, that the balance of the motive column available for overcoming the resistance of the downcast and upcast would be 1.867 lb. per sq. ft.—*i.e.*, 2.468 lb. per sq. ft. − 0.601 lb. per sq. ft. As already mentioned, definite upcast resistance figures could not readily be ascertained at the time of the test. The total resistance of the upcast was assumed approximately as being half that of the downcast, on account of the dissipation of air throughout the mine and the upcast being through several openings. By equating the downcast and upcast resistance to the 1.867 lb. per sq. ft., a friction coefficient for the downcast of $\frac{.4}{10^8}$ was obtained. It is, of course, apparent that the above value for K for the downcast, on account of the assumptions necessary for the upcast resistance at the present time, is very approximate. Under altered upcast conditions, and also with a fan working, it is hoped that a definite figure may be arrived at for the downcast. It may be noted that the lowest value of K, given in Peele, for a mean radius of 1, approximating to that of the shaft compartments, is $\frac{.165}{10^8}$ for stone arched headings.

As the resistance of the downcast is a controlling factor in the quantity of air which will enter any mine through it at any given pressure, it seems important that some trouble should be taken in ascertaining the resistance figure as closely as possible.

At the time of the test the lowest level (No. 8) directly connected to the downcast shaft was partially under water, and hence inaccessible. The general trend and the quantities of air circulating under those conditions was observed. Then all openings to this level were covered over, isolating it as completely as possible. Immediately prior to the covering over, air on two of the higher levels (Nos. 6 and 4) was short-circuiting into the downcast shaft. As soon as the covering of the downcast was complete, the direction of the air-current on the lower of these two levels reversed, air entering it from the downcast. On uncovering subsequently, after an interval of two to three weeks, downcast air still entered the level, and still continues to do so. The temperature on the day on which the short-circuit was in evidence was very high, and the motive column of the mine exceedingly low—less than 1 lb. per sq. ft. The short-circuit was a distinctly unusual feature, and was noted only on the one occasion.

The higher short-circuit on No. 4 level, which was also observed for the first time, was persistent over a period, and still exists with natural ventilation. An interesting feature arose, at a later period of the test, concerning the short-circuiting of air from this level into the downcast shaft. With increased motive column acting on the mine, instead of the short-circuiting air coming from the upcast end of the mine and back into the downcast, as had previously been the case, it was actually surface air entering through the mullock passes open to the surface north of the downcast shaft, and travelling along portion of the level into the shaft. The level in question (No. 4) is 480 ft. below the collar of the downcast shaft, and the shaft has no air-outlet between it and the surface. The vertical distance between the remaining levels connected from the downcast to the main shaft is 171 ft., 148 ft., and 134 ft. respectively. The following appears to be a direct explanation of this later short-circuit.

With the greater motive column in operation, and a consequently greater quantity of air in circulation in the mine, the resistance of the downcast shaft over the 480-ft. length, for its increased quantity of air, became so great that surface air entered the mullock passes until the resistance of the quantity in circulation through each of them equalled the main downcast resistance for this section of 480 ft. The resistance of the succeeding sections of the downcast shaft being much less, on account of their shorter length, the shaft naturally would take a greater quantity of air to maintain a pressure equal to that of the first section, and the only possible source of supply was from the level, thus creating the short-circuit.

In the case of the short-circuiting extending right from the upcast end of the mine, on account of the lower motive column and consequent shortage of supply through the mullock passes, the increased air necessary to equalize the resistance throughout the shaft was drawn from the upcast end. The obstructed state of the upcast would also be a factor in this connection.

Combined with this question of short-circuiting is that of the motive column acting on each level of the mine and the effect of variations in the maximum motive column. On days of low motive column, by far the greater proportion of the total incoming air went to the lowest level. As the total motive column increased, a slightly greater quantity of air was taken by the lower level, but the greatest part of the additional incoming air went to the level immediately above, with a small increase in the quantity going to the levels still higher up. This distribution of air would appear to be chiefly a matter depending on the motive column acting on the various levels, combined with the fact that the frictional resistance increases as the cube of the quantity of air circulating. Experiments in this direction at some future date are proposed, with the fan in operation, thus largely increasing the motive column. Upon the results obtained would depend the regulation by means of doors or similar contrivances of the quantities necessary for each level.

Many experiments have been carried out using temporary doors on the levels, and covering over the mullock passes, with a view to controlling the distribution of air throughout the various portions of the mine and preventing local short-circuits through the mullock passes. The material used for these temporary doors and coverings was No. 1 house canvas, which proved to be both convenient and sufficiently effective. The results obtained from these temporary arrangements will be used in devising a permanent system for this purpose. The details, however, are of no general interest.

The question of diffusion has not been mentioned. It is difficult to secure any figures on the subject for the conditions which obtain underground. The ventilation of workings where the air-current is weak is assisted by diffusion, whilst the supply of fresh air to those portions of the mine outside the circuit of ventilating current is entirely dependent on the power of diffusion. Under the latter condition it has been stated that a room 20 ft. x 8 ft. may be driven for 500 ft., and a room 10 ft. x 8 ft. for 250 ft. The matter warrants investigation in connection with development places and any levels which are not in any way connected with the downcast, but has not yet been carefully considered, the chief object up to the present having been that of bringing the ventilating current directly in contact with the various working places throughout the mine. For these places, however, unaffected to any great extent by the main air-current, subsidiary artificial ventilation by small fans or other similar means will probably prove more satisfactory than any diffusion method.

With regard to the behaviour of the main shaft during these operations, difficulty often arose over its variability while the test was in progress. Under ordinary working conditions it acts as a downcast, but under the conditions of the test it acted as an upcast in regard to some levels and a downcast in regard to others, and was not consistent for any particular level.

From the readings obtained the moisture contents of the air at various points were calculated in grains per cub. ft. In obtaining these results the variations in temperature and pressure at the different places were taken into account, so that the moisture content was expressed for a given mass throughout. Graphs were prepared showing the moisture in grains per cub. ft., and the corresponding lengths of air-way between the stations at which the readings were taken. On the same graph the wet-bulb and dry-bulb temperatures were also plotted against the lengths of air-way. These gave a quick and clear conception of the condition of the air at any particular point, and also a good general idea of the stages through which the comparatively dry downcast air attained complete saturation by the time the upcast was reached.

An excellent discussion of the question of moisture in underground air is given in the *Transactions of the Institution of Mining Engineers*, vol. lviii., part 4.

These investigations, as already mentioned, were undertaken under conditions of purely natural ventilation. This, however, was an advantage rather than otherwise, as it was possible to obtain a series of results affected only by natural causes. Regarding the practical value of the work carried out, some indication of the application of the information obtained from the test may be desirable. Considering, first, the downcast shaft, the frictional-resistance figures showed that the area was insufficient for the quantity of air desired to be put in circulation, unless a higher water-gauge were maintained than appears desirable. Accordingly, the pump and ladder-way compartment of this shaft (whose area is equal to the combined areas of the other two compartments) is to be completely reconstructed, the solid timber stages being replaced by iron grids, and a general re-arrangement of air and water pipes being made. Thus the full benefit of the area of this shaft will be obtained for ventilating purposes. Further, even with these adjustments, it is probable that the downcast area will be insufficient, and arrangements have been made to throw into commission three or more of the south end mullock passes to supplement the supply of downcast air. The flow of air resulting from the installation of any fan running at a given water-gauge must of necessity depend on the area of the passages through which the air circulates, hence the attention to the downcast air-ways, as these play an important part in regulating the quantity of air entering the mine.

Certain sections of the upcast were too small, and in these sections additional openings are being made. In cases where it was not desirable to excavate larger air-ways, auxiliary fans of suitable capacity and water-gauge are being installed. A system of underground fans will also be installed to meet conditions in workings which are outside the main ventilating current.

Considering the distribution of air as between the levels and stopes, the system of stoping will be modified to obtain a greater circulation through the stopes, so that the natural upward course of the heated air may be preserved as far as possible. Larger inlets into the stopes will also be made. The regulation of the quantity of air entering the various levels is being arranged according to the requirements of each level.

These are a few of the more general deductions made from the results obtained in the test. There are many others, but many of them are of local interest only. The above are put forward more as an indication of the value of the method than otherwise.

The author trusts that the general scheme put forward will be found interesting by those whom this question affects, although they may not agree with his ideas on the subject.

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DETERMINATION OF MINUTE AMOUNTS OF LEAD IN WATER, WITH NOTES ON CERTAIN CAUSES OF ERROR.

BY D. AVERY, A. J. HEMINGWAY, V. G. ANDERSON AND T. A. READ.

IN the determination of very small amounts of lead, the usual analytical methods are far from being satisfactory. Small amounts of lead may be present in the reagents employed, and it is customary to run a blank experiment to correct the error arising in this way. When the correction is of small magnitude compared with the amount of lead in the sample, this procedure may be adopted ; but when very small amounts of lead are being determined it may happen that the lead found in the blank is as much, or even more, than the lead actually present in the sample, and the analysis has to be rejected. Moreover, the blank experiment cannot check errors which are not common to the blank and the analysis itself – *e.g.*, the apparatus used in the parallel experiments, etc.

It seemed to be desirable, therefore, to make an investigation of the problem to ascertain, as far as possible, the nature of the errors arising from the introduction or loss of lead during the analysis, and how far these could be eliminated or corrected for ; also, to determine the limits of accuracy of the improved method and the minimum amount of lead that could be reliably estimated.

In the investigation, reliability and sensitiveness were regarded as essential features. Speed of operation, on the other hand, was considered of less importance.

The amounts of lead dealt with being usually less than 1 mg., there is no alternative to the use of a colorimetric method. The latter, depending as it does upon the development of a brown coloration when ammonium sulphide is added to a very dilute solution of a lead salt, is far from being a characteristic test for lead. Indeed, it is well known that the salts of most of the commonly occurring metals interfere with this test. Hence it is of vital importance that the lead should be isolated in the form of a pure compound possessing quite definite and characteristic properties before the colorimetric estimation is proceeded with.

(This paper is separately bound, and may be, if so desired, detached complete from this number.)

The problem is more complicated if organic matter is present, since this would interfere with the determination, and it must therefore be eliminated ; hence the question may be attacked from two points of view, according to the presence or absence of appreciable amounts of organic matter.

The first case to be considered is that in which organic matter is substantially absent, and any other inorganic substances, if present, are not in large amount—for example, drinking waters.

OUTLINE OF METHOD.

Previous experience indicated that a satisfactory method for the determination of minute traces of lead in water should include the following steps :—

(1) Filtration of the sample (the sediment being set aside for separate examination).

(2) Examination of filtrate—

  (*a*) Evaporation of from 2 to 5 litres of the filtered water to about 100 cc.

  (*b*) Separation of lead sulphide by means of sulphuretted hydrogen in dilute hydrochloric acid solution.

  (*c*) Conversion of lead sulphide to lead nitrate and subsequent separation of the lead as lead sulphate.

  (*d*) Colorimetric determination of the lead after dissolving the lead sulphate in a solution of ammonium acetate.

(3) Examination of the sediment by treatment with hydrochloric acid and then proceeding as in the case of water (steps *b*, *c*, and *d*).

LIMIT OF SENSITIVENESS.

It was considered that an attempt should be made to develop the maximum possible sensitiveness in the method. At the outset it was found that in the known absence of interfering metals as little as 0.005 (1/200) mg. of lead can be detected colorimetrically. But the smallest weight of lead which can be chemically isolated and rendered visible in the form of lead sulphate was found to be about 0.02 (1/50) mg. This amount, therefore, probably represents the least amount of lead which can be manipulated under laboratory conditions. Supposing 0.02 mg. of lead were isolated from

2 litres of water, it would represent one part of lead in 100,000,000 of water, or 0.01 mg. per litre. These preliminary considerations indicate that it should be possible to develop a method capable of detecting down to 0.01 mg. of lead per litre. Such a method would be a distinct advance on current practice. Hitherto, in the examination of water for lead, amounts less than 0.1 mg. per litre have been regarded as negligible.

SPECIAL DIFFICULTIES INVOLVED.

Needless to say, in developing a method on these lines extreme precautions must be taken to eliminate sources of error which would be quite inappreciable in estimating lead in ordinary samples, as, for example, ores. The greatest care must be exercised to prevent the introduction of lead during analysis from sources other than the water under examination. Then, again, loss of lead must be guarded against. In an ordinary lead determination a milligram of lead may, without serious consequences, be lost as the result of the solubility of lead sulphate in the precipitating solution, but in many instances a milligram would represent about 50 times the amount of lead in the actual determination. The errors due to gains and losses of lead will be considered in detail under the following headings :—

(1) Investigation of errors due to the introduction of lead from outside sources.
(2) Investigation of errors arising from the method of analysis.

I.—ERRORS DUE TO INTRODUCTION OF LEAD FROM OUTSIDE SOURCES.

Lead compounds, and lead itself, are in such general use in modern life that almost every substance coming into contact with the water being examined has to be rigorously examined for lead. Errors arising from the possible introduction of lead may be considered under the following sub-headings :—

(i.) Sample containers.
(ii.) Chemical reagents.
(iii.) Apparatus.
(iv.) Atmospheric dust.

(i.) *Sample Containers.*—In the first place, special care must be exercised in the selection of the sample containers. The containers in the present investigation were the ordinary $\frac{1}{2}$-gallon "Winchester" bottles, but larger bottles, holding about $\frac{3}{4}$-gallon, were employed in some instances. An examination was considered necessary, as some of the samples were stored in the bottles for a week or more before being tested for lead. Some of the Winchesters were tested by treating them with hot hydrochloric acid, and others, again, were tested by storing in them for a week or more a quantity of lead-free distilled water, and afterwards examining the water for lead.

Acid Treatment.—20 cc. of lead-free hydrochloric acid (sp. gr. 1.18) were heated to boiling and poured into the Winchester and rinsed around the inside surface of the bottle several times. The Winchester was then set aside for 24 hours, but was occasionally shaken up. The acid was then removed, the bottle rinsed with pure water, the acid and rinsings evaporated, and the lead estimated by the method described in detail later.

Water Treatment.—The selected Winchesters were almost filled with lead-free distilled water and set aside for 7 days, but were shaken up once a day. The water was then evaporated and the lead determined. Blank experiments on reagents and apparatus were made concurrently in all cases.

The results obtained were as follows :—

TABLE I.

Winchester.		Treatment.	Milligrams of Lead.		
No.	Capacity.		Total lead found.	[*] Lead found in blank experiment.	Differences.
	Litres.				
1	3.5	acid	0.010	0.010	—
2	3.5	,,	0.010	0.010	—
3	2.5	,,	0.015	0.010	+0.005
4	2.5	,,	0.020	0.010	+0.010
5	2.5	,,	0.015	0.010	+0.005
6	2.5	water	0.033	0.025	+0.010
7	3.5	,,	0.020	0.030	−0.010

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[*] As the investigation proceeded it was found that the amount of lead in the blanks could be considerably reduced.

These results clearly show that no appreciable amounts of lead were taken up by the water samples from the collecting bottles used in the investigation, the total amount of lead found being always less than 0.015 mg. per litre, and the lead actually taken up from the bottle being probably very much less.

(ii.) *The Chemical Reagents.*—It is well known that some chemical reagents carry traces of lead. This may be derived in certain cases —*e.g.*, sulphuric acid—from lead appliances used in their manufacture, but in other cases the lead is no doubt taken up from bottles made from glass containing lead. In this investigation the purest possible reagents were obtained, and these were, with one or two exceptions, again purified by distillation in all-glass, lead-free apparatus. Lead-free glass bottles were used also for storing the reagents. Comparatively small amounts were distilled at a time. so that the period of storage was usually short. So successful were these efforts that numerous " blank " experiments made from time to time on reagents invariably showed no trace of lead when examined by the most delicate test available. A list of the reagents purified by re-distillation is as follows :—

Reagent.	Amount used in each analysis.	Remarks.
1. Water	300–400 cc.	
2. Hydrochloric acid	2 cc.	Concentration about 6N.
3. Nitric acid ..	4 cc. of 1 : 1	Distilled from large glass retort.
4. Sulphuric acid ..	1 cc.	Distilled from small glass retort.
5. Ammonium hydroxide ..	1 cc.	Distilled from large glass retort.
6. Acetic acid ..	Used in ammonium acetate	B.P. Glacial acetic acid, distilled from large glass retort.
7. Alcohol	about 20 cc.	Absolute alcohol.

The other reagents used were :—

Reagent.	Amount used in each analysis.	Remarks.
8. Hydrogen sulphide	as required	Made from ferrous sulphide and washed with water.
9. Potassium cyanide	1 cc. of a 10 % aqueous solution ..	May and Baker's pure.
10.*Ammonium acetate	10 cc. 1 : 2	Made from Nos. 5 and 6, and diluted with twice its own volume of water.
11. Ammonium sulphide	0.3 cc.	Made from Nos. 5 and 8.

Difficulties sometimes occurred in respect to certain batches of re-distilled ammonia. On neutralization with re-distilled glacial acetic acid a slight yellow colour developed, which became more intense on boiling. This colour interfered with the coloration work, and the reagent was rejected. The ammonium acetate should be quite colourless, and should remain so on being boiled for some time. In certain cases it may be necessary to prepare pure ammonium hydroxide solutions from pure ammonium chloride and lime.

No. 1 Standard Lead Acetate Solution (Stock), 1 cc. = 0.0001 grm. lead.—Prepared by dissolving 0.1463 grm. of pure lead sulphate in ammonium acetate solution and diluting to 1 litre.

Note.—This solution keeps for a considerable time.

No. 2 Standard Lead Acetate Solution (Dilute), 1 cc. = 0.00001 grm. lead.—Prepared by diluting 100 cc. of No. 1 (stock) solution to 1000 cc. with pure water.

Note.—This solution does not keep well, and should be made up at least every day or two.

(iii.) *Apparatus.*—The water and reagents come into contact with the following apparatus in the course of analysis :—

- (*a*) Porcelain ware—evaporating basin.
- (*b*) Glassware—flasks, beakers, funnels, Nessler glasses, stirring rods.

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* Ammonium hydroxide and acetic acid.

(*c*) Filter papers—4 filter papers are used in each analysis.

(*a*) Porcelain Ware.—The first operation after the preliminary filtration involves the evaporation of several litres of water nearly to dryness. This means that the water at the boiling-point is in contact with the evaporating dish for from 4 to 6 hours. Some acid was always added near the end of the operation, so that lead, if present in the glaze, would be likely to dissolve. The evaporating basins used were of hard, non-porous chemical porcelain (S.C.P. ware), and were glazed on the inside surface. They were 10 in. in diameter, and held about 2 litres.

It is well known that lead compounds do not enter into the composition of chemical porcelain, but zinc oxide is sometimes a constituent of the glaze. Such zinc oxide would almost certainly contain traces of lead (perhaps up to 0.1 %). In any case the amount of lead would be very small, and would be present as a highly insoluble complex silicate. Before use the basins were filled with water and kept at the boiling-point for several days, and were then digested with boiling dilute hydrochloric acid for a further period.

Tests were carried out with the basins by evaporating in them 2.5 litres of lead-free water and examining the evaporated solution for lead according to the usual method. The results were as follows:—

TABLE II.

Amount of lead taken up during the evaporation of 2.5 litres of water in porcelain basin.

Description of Water.	Total lead found.
Distilled water.	0.025
,, ,,	0.035
Melbourne tap water.	0.015

The results show that variable but small amounts of lead are taken up, and that the average amount does not exceed 0.01 mg. per litre of water evaporated.

(*b*) Glassware.—Japanese glassware ("non-alkali"), similar in composition and properties to Jena glass, was used throughout, except in the case of funnels and glass rods. This glass contains up to 10 % of zinc oxide, and therefore probably contains minute traces of lead also; but as the glass is highly resistant to the solvent action of water and acids, very little lead would be dissolved during the course of an experiment. It was found that no lead was taken up from the funnels, tubes, and glass rods (Bohemian glass). Large glass flasks (1.5 litres) were used in certain cases to evaporate the water, the flasks being fitted with delivery tubes and condensers. The results of three experiments in which 2.5 litres of lead-free water were evaporated to 100 cc. are as follows:—

TABLE III.

Amount of lead taken up during the evaporation of 2.5 litres of water in glass flasks.

Description of Water.	Total lead found.
Melbourne tap water.	0.025
Distilled water.	0.015
,, ,,	0.015

These results show that the amount of lead taken up during the evaporation of 2.5 litres of water does not exceed 0.01 mg. per litre.

It seemed probable that some lead would be taken up during the evaporation of the excess nitric acid and the subsequent evaporation with sulphuric acid before separating the lead as sulphate. A series of tests, however, showed that not more than 0.005 mg. of lead is taken up during this rather drastic but necessary step in the process.

(c) Filter Papers.—The filter papers used throughout were J. Green's "double washed," No. 2. One 12.5 cm. paper, one 11-cm., and two 9-cm. papers were used for each determination. It was found that each paper contained minute amounts of lead and iron. The presence of lead in the papers was quite unexpected, and may be due to the fact that one of the acids used in the double-washing process was hydrofluoric acid. Washing with this acid would no doubt be done in leaden vessels.

The amounts of lead and iron found would be of no consequence in an ordinary analysis, and even in the present instance the error introduced in the course of a determination by the combined effects of iron and lead was less than 0.015 mg. of lead. This source of error should not, however, be overlooked, and the following treatment of each filter paper immediately before use is recommended :— The filter paper, after being folded and adjusted to the funnel, is subjected to two successive treatments with 3 cc. of hot dilute (1 : 2) hydrochloric acid, the latter being well distributed by means of a pipette. The paper is then washed thoroughly with hot water. A hot solution of ammonium acetate (1 : 2) in two portions of 5 cc. each is then poured over the paper, which, after further washing with hot water, is ready for use. Papers treated in this way were lead and iron-free.

To summarize, it may be said that if proper precautions are observed the total amount of lead taken up from the apparatus during the course of an experiment need not exceed 0.01 mg. per litre of water operated upon.

(iv.) *Atmospheric Dust.*—In localities where either lead-mining or metallurgical operations are conducted, the possibility of serious contamination by atmospheric dust is to be expected. But in every city lead paints are commonly employed, and it is well known that the lead pigment is set free in the form of a fine powder when the vehicle perishes on exposure to atmospheric influences. Consequently, even in Melbourne, where this investigation was conducted, there was a possibility of contamination by lead-bearing dust. The latter can be excluded during the preliminary filtration of the water; but while evaporating 2.5 litres of water in a 10-in. porcelain basin a considerable area is exposed to the air of the laboratory for about 4 hours. Then, again, in the three subsequent filtrations it is hardly possible to shield the filters entirely. Fortunately, the laboratory conditions were favorable in this respect. A large number of blank experiments were made at different times, and, while it is impossible to say that no lead at all came from the atmosphere, the amount was very small, and quite negligible compared with other sources of error.

The experiments recorded above, in which the water was evaporated in flasks fitted with delivery tubes, were intended to test this point. Considering the difficulties involved in the exact determination of very small quantities of lead, it cannot be said definitely that less lead was found when flasks were used than in the case of open basins. The difference might easily have been due to the fact that in one case *glass* flasks were used, and in the other *porcelain* basins.

II.—ERRORS ARISING FROM THE METHODS OF ANALYSIS.

This section may be subdivided into seven sub-sections, corresponding respectively to the six steps of the process and the method as a whole, as follows :—

1. Filtration of the water (separation of sediment).
2. Evaporation.
3. Separation of the lead and second-group metals as sulphides.
4. Separation of the lead as sulphate.
5. Colorimetric estimation of the lead.
6. Treatment of the sediment.
7. The complete method.

Each step in the method consists of a number of operations, all of which were carefully scrutinized, and, when necessary, carefully tested by experiment.

(1) *Filtration of the Water.*—It was noticed that, although many samples appeared to be perfectly clear when first collected, practically all of them exhibited appreciable amounts of sediment after standing in glass bottles for a few days. The question of the distribution of the lead between the clear liquid and the sediment naturally presented itself, and it was considered desirable from several points of view to filter all samples and to examine the filtrates and sediments separately.

This step is a comparatively simple one, so that, with ordinary precautions, there is hardly a possibility of error. As large volumes of water were to be filtered, an automatic filtering apparatus was fitted up and used throughout the investigation. This appliance, which works on the " bird-feed " principle, is well known. The chief advantage gained by the use of this apparatus is that the water may be protected from dust during filtration. A saving of time is also effected, as the filtration may be carried out overnight without attention.

The filter paper used should preferably have been treated with the dilute hydrochloric acid and ammonium acetate solution. It is necessary to return the first portion of water which passes through the filter paper.

(2) *Evaporation.*—From 2.5 to 5 litres of the filtered water were usually evaporated by heating in a 10-in. porcelain basin. When only 100 cc. remained, 2 cc. of 6N hydrochloric acid were added, and the heating was continued for about 5 minutes.

This step of the process is also relatively simple, and, carried out as described above, there is no loss of lead during evaporation. If the water contains calcium carbonate or calcium sulphate, care must be taken that complete re-solution takes place on digesting after the addition of hydrochloric acid. Should the water be alkaline, it may be necessary to use more than 2 cc. of 6N hydrochloric acid. In this case hydrochloric acid should be added until the solution possesses a faint acid reaction, and then a further 2 cc. added.

(3) *Separation of the Lead as Lead Sulphide.*- Before proceeding further, it is necessary to filter the acidified solution through an 11-cm. filter paper into a 300-cc. Erlenmeyer flask, the filter paper and dish being washed well with boiling water. After cooling, the total volume of the solution is made up to 250 cc. with distilled water. Washed hydrogen sulphide is then slowly bubbled through the cold solution for one hour. The solution is then set aside and allowed to stand in the cold overnight. In the following morning it is filtered through a 9-cm. filter paper, the flask being washed out three times with a small quantity of cold water (saturated with hydrogen sulphide), and the filter paper three times, also with the same liquid. The use of accelerated filtration is inadvisable in this work. The flask in which the precipitation is made is preferably fitted with a rubber stopper perforated with two holes. Through one of these a straight glass tube passes nearly to the bottom of the flask, the end of the tube being drawn out into a fine jet. Through the other hole another glass tube, bent at a right angle, is passed, one end going through the stopper for a distance of about half an inch. By the use of this device the solution is protected from the dust or accidental contamination, with the further advantage that precipitation takes place under slight pressure.

In this step of the process a very serious loss of lead may occur unless the conditions set out above are rigidly adhered to. In deciding upon the conditions under which the precipitation of lead sulphide should be made, the authors were in the first instance guided largely by the work of Strell, whose valuable work on the precipitation of lead as sulphide is quoted by Ibbotson and Aitcheson in their book on "The Analysis of Non-Ferrous Alloys." According to Strell, precipitation of lead is complete from $\frac{N}{10}$ acid solution of lead chloride at ordinary room temperatures. But, whereas Strell experimented with several centigrams of lead chloride, in the present case only a few one-hundredths of a milligram were involved. Several uncertainties, therefore, remained—for example, the solubility of lead sulphide might be such as to account for a considerable loss of lead; or, again, granting that lead sulphide is completely precipitated, is it possible to collect and wash very minute quantities upon a filter paper without loss? This stage of the process was tested by taking known quantities of standard lead-acetate solution, adding 2 cc. of 6N hyrdochloric acid, and diluting to 250 cc. with water. The acidity of this solution was approximately 1/20N. Blank experiments with water and acid only were also made. These solutions were then saturated with hydrogen sulphide, allowed to stand (cold) overnight, filtered, and washed exactly as described above. The filter papers, after filtration, were treated with 2 cc. of hot dilute (1 : 1) nitric acid, which was run out from a pipette, followed by another 2 cc. of same reagent. The solutions were caught in the precipitating flasks, and were neutralized with 2.5 cc. of re-distilled ammonia. The lead was determined colorimetrically.

The results were as follows:—

TABLE IV.

The separation of lead in $\frac{N}{20}$ hydrochloric acid solution by means of sulphuretted hydrogen.

Conditions:—

Hydrochloric acid = 2 cc. of 6N acid.
Total volume = 250 cc.
Temperature = about 20° C.

No.	Lead added (milligram).	Lead found (milligram).
1 (blank experiment)	nil.	nil.
2	0.01	0.005
3	0.02	0.015
4 (blank experiment)	nil.	nil.
5	0.05	0.05
6	0.10	0.10
7 (blank experiment)	nil.	nil.
8	0.20	0.20

When the above solutions were saturated with hydrogen sulphide no visible darkening occurred, and even on standing overnight no precipitate except what appeared to be a trace of sulphur could be seen ; but it is evident that practically complete precipitation occurs under the conditions specified. Apparently, also, the physical condition of the precipitate is such that it is retained upon the filter paper, and can be washed without appreciable loss.

In another series of experiments 0.1 grm. of copper sulphate was added to each test before precipitation in the hope that the relatively large amount of copper sulphide formed would assist in collecting the small amount of lead sulphide. It was found, however, that the copper sulphide did not settle well under the conditions of the experiment, and, in view of the satisfactory results obtained in the previous series, the use of copper sulphate was abandoned.

(4) *Separation of Lead as Lead Sulphate.* The previous step ensures the separation of lead from all metals except those of the second group. The object of the present step is to separate the lead without loss from such second-group metals as may be present. The difference in solubility of lead sulphate, on the one hand, and the sulphates of the second-group metals on the other, in certain mixtures of water, sulphuric acid, and alcohol, forms the basis of this separation, the problem being to find the conditions under which lead sulphate will be highly insoluble and the other sulphates readily soluble.

The available solubility data relating to lead sulphate, although conflicting, was made use of as far as possible in the preliminary experiments. Finally, a mixture containing approximately 65 volumes of water, 32 volumes of absolute alcohol, and 3 volumes (5 per cent. by weight) of sulphuric acid, was used. The solubility of lead sulphate in this solution was approximately estimated and found to be sufficiently low for the purpose. It is interesting to compare the approximate solubility of lead sulphate in pure water, dilute sulphuric acid (5 % by weight), and the above mixture respectively.

Approximate Solubility of Lead Sulphate at 20° C.

	Milligrams per 100 cc.
Pure water	4.5
Water containing 5 % of sulphuric acid	1.0
A mixture containing water 70 %, alcohol 25 %, sulphuric acid 5 % (by weight)	0.05

It is evident that the use of alcohol in suitable proportion reduces the solubility of lead sulphate very considerably, and that its use in the present work was imperative.

The precipitate of lead sulphide, and other sulphides of second-group metals, if present, is dissolved by dropping 2 cc. of hot (1 : 1) nitric acid around the paper from a pipette, followed by another 2 cc. of the same reagent, catching the solution in the original Erlenmeyer flask. Wash the filter six times with hot distilled water. These operations should be conducted whether a precipitate can be seen or not, for quite a considerable amount of lead may be present without being visible. Warm the solution in the flask and evaporate to about 20 cc.; then transfer to a 50-cc. cylindrical beaker (non-alkali) glass, washing out the flask three times with warm water. Evaporate quietly to about 5 cc. on a hot plate, then add 1 cc. of sulphuric acid, and continue the evaporation until the nitric acid has been eliminated, and strong white fumes appear. Cool, add 20 cc. of cold distilled water and 10 cc. of absolute alcohol, mix well, and allow to stand overnight. Filter through a 9-cm. paper, washing out the beaker with a solution of water, alcohol, and sulphuric acid, of the same composition as the original solution, then wash the filter paper three times with the same solution.

This step of the process was tested by a series of experiments, in which known amounts of lead were added to 4 cc. of 1 : 1 nitric acid in a 50-cc. beaker, together with 1 cc. of sulphuric acid. The solutions were then evaporated until the appearance of copious white fumes indicated that the nitric acid had been expelled. After cooling, 20 cc. of water and 10 cc. of alcohol were added, the beaker set aside overnight, and the lead sulphate separated exactly as described above. The lead sulphate was then dissolved in ammonium acetate and determined colorimetrically. Two blank experiments were run side by side with the above.

The following are the results:—

TABLE V. (*a*).

Separation of Lead as Lead Sulphate from a Dilute Solution of Sulphuric Acid containing Alcohol.

Conditions:—

Total volume	31 cc.
Sulphuric acid	1 cc.
Alcohol	10 cc.
Water	20 cc.
Temperature (approximate)	20° C.

No.	Lead added (milligrams).	Lead found (milligrams).
1 (blank experiment)	nil.	nil.
2 (blank experiment)	nil.	nil.
3	0.01	nil.
4	0.02	0.005
5	0.05	0.04
6	0.10	0.09

A further series of tests was afterwards made, in which the lead in the alcoholic filtrate was also determined colorimetrically, the results being as follows :—

TABLE V. (*b*).

No.	Lead added.	LEAD FOUND.	
		As sulphate.	In alcoholic filtrate.
7	0.05	0.04	0.01
8	0.05	0.04	0.01
9	0.10	0.09	0.015
10	0.10	0.09	0.015
11 (blank experiment)	nil.	nil.	nil.

There is an uncertainty of the order of 0.005 mg. in the results obtained by the colorimetric method even under the most favourable circumstances. It is clear, however, that, owing to the solubility of lead sulphate, there is a definite loss of about 0.01 mg. of lead in the filtrate and washings at this stage of the process.

From the point of view of the insolubility of lead sulphate the conditions specified were now considered to be satisfactory, but there yet remained the question of the solubility of the sulphates of the other second-group metals. Another series of tests was conducted, in which about 1 mg. of mercury, copper, bismuth, and tin respectively were evaporated with 4 cc. of nitric acid and 1 cc. of sulphuric acid, and the sulphates treated as described above.

The results showed that mercury, copper, and tin in small quantities are completely separated under the conditions specified, but the same cannot be said of bismuth. It was found that, owing to the tendency of bismuth to form a basic sulphate, it was necessary to wash *six times* with the acidulated alcohol-water solution in order to entirely eliminate the last traces of bismuth. When the presence of bismuth is suspected this precaution must therefore be taken.

(5) *Colorimetric Estimation of Lead.*—The basis of the colorimetric determination of lead is the production of a brown coloration when ammonium sulphide is added to a very dilute solution of a lead salt. The intensity of the coloration produced is usually compared with that produced by known amounts of lead under the same conditions. It is of the utmost importance that the standard should be made up and compared under exactly the same conditions as the assay. Not only should the two solutions contain the same ions in exactly the same proportions, but both solutions should be perfectly colourless before the addition of ammonium sulphide if reliable results are to be obtained. All reagents used must be tested with ammonium sulphide under the conditions of the test and yield perfectly colourless solution when compared with distilled water in Nessler glasses. It is recommended that this step of the process should be conducted as follows :—

Dissolve any precipitate of lead sulphate (see step 4) by dropping 5 cc. of hot (1 : 2) ammonium acetate solution (from a pipette) around the filter paper, followed by another 5 cc. of the same reagent, catching the solution in the precipitating beaker. Wash the filter six times with hot water. When cool, the solution is ready for the colorimetric estimation of lead.

Comparison with the standard—the so-called "Nesslerizing"—is carried out in the following manner :—

Transfer the assay solution to a 50-cc. Nessler tube, add 1 cc. of 10 per cent. potassium cyanide solution and 1 cc. of ammonium hydroxide, mix well, and make up to the 50-cc. mark. Then add 0.3 cc. (six drops) of freshly-prepared ammonium sulphide solution and mix again, using a glass plunger for the purpose. The brown colour (yellow in the case of minute amounts) indicating the presence of lead is compared with a solution made up as follows :—In another Nessler glass, corresponding exactly in capacity and dimensions with the first, place 10 cc. of (1 : 2) ammonium acetate, 1 cc. of 10 % potassium cyanide, 1 cc. of ammonium hydroxide, and about 30 cc. of distilled water, mix well, and add 0.3 cc. of ammonium sulphide solution. To this solution, which must be colourless, add standard lead-acetate solution (1 cc. = 0.00001 grm. Pb), 0.5 cc. at a time, with stirring after each addition until the intensity of the colour in both tubes is the same. A simple colorimeter is recommended for making the comparison. It is advisable to arrange the strength of the assay solution so that not more than 8 cc. of the standard solution is required. If much lead sulphate precipitate was noticed after the addition of alcohol, the solution in ammonium acetate should be made up to a definite volume (say 100 cc.), and an aliquot part taken for comparison, so that not more than 8 cc. will be required. In this case the same proportion of ammonium acetate must be added to the standard as is contained in the aliquot part of the assay solution.

It is desirable in all cases to regard the first comparison as a trial, and to make up another standard in which the required lead acetate solution is added *before* the ammonium sulphide, and, along with the ammonium acetate, potassium cyanide, ammonia, and water, to make a total of 50 cc. The solution is mixed well, and 0.3 cc. of ammonium sulphide added, and, after further mixing, compared with the assay. Slight additions (not more than 1 cc.) may then be made to either assay or standard in order to match them, and the necessary corrections made.

The above conditions were worked out after a great number of tests had been carried out, the results of which it is impossible to give in detail. It will be sufficient to note that errors of considerable magnitude may easily occur unless great care is observed. It is important to compare only amounts up to 0.08 mg., especially when the dilute lead solution is added *after* the ammonium sulphide. The following test will show the magnitude of the errors involved when working under the specified conditions. Two sets of solution were made up with known amounts of lead and the necessary reagents added. The first one was regarded as the standard, the second as the assay. The results were as follows :—

No. 1 (lead taken). Mg.	No. 2 (lead found). Mg.
0.01	0.005
0.05	0.055
0.08	0.085

This indicates that when the solutions to be compared are made up even under the same conditions the results agree only to 0.005 mg. between the limits 0.01 and 0.08 mg. lead. These results were amply confirmed by other experiments. Under the conditions given the discrepancy does not exceed 0.005, and, of course, sometimes the results agree absolutely.

It was important to find out the effect of time upon the intensity of coloration produced. A series of standards was made up and compared with another series prepared exactly as before, but 15 minutes later. The results were as follows:—

Lead taken (Zero time). Mg.	Lead found (15 mins. later). Mg.
0.01	0.01
0.05	0.05
0.08	0.08

Still another series was prepared after the original set had stood for 30 minutes. The results were:—

Lead taken (Zero time). Mg.	Lead found (30 mins. later). Mg.
0.01	0.015
0.05	0.050
0.08	0.085

The above results show that the colour develops to a maximum almost immediately, and remains unchanged for at least 30 minutes; but the results are subject to a possible error of nearly 10 % of the amount of lead in the most favourable cases, and this error may rise to about 50 % present in the case of very small quantities.

It may be noted that, as the comparisons are conducted in alkaline sulphide solutions, traces of arsenic, antimony, and tin compounds do not interfere with the results, even if not completely separated earlier. Traces of copper do not interfere in the presence of potassium cyanide.

(6) *Treatment of the Sediment.*—The residue from the first filtration of the water is treated on the filter with hot hydrochloric acid by running the acid from a pipette around the paper. A second treatment with the same reagent is given, the filtrate being in each case allowed to run into the bottle which contained the original water

sample. The paper is then washed six times with boiling water. The solution is washed around the inside of the bottle several times and then transferred to a 300-cc. beaker of "non-alkali" glass, the bottle being washed three times with hot water. The solution is evaporated just to dryness, and 2 cc. of hydrochloric acid and 10 cc. of water added. This solution is heated and filtered through a 9-cm. filter paper into a 300-cc. Erlenmeyer flask, cooled, made up to 250 cc. with water. The solution is now ready for precipitation of the lead as sulphide, and the subsequent analysis is conducted exactly as described in the case of water (sub-sections 3, 4, and 5 above).

A number of blank experiments indicated that 0.02 mg. of lead was taken up in the course of this determination, but that otherwise no serious error was involved.

The examination of a number of samples of water has shown the importance of examining the sediment in this way; a large proportion of the lead present is usually found in the sediment.

(7) *Testing of the Complete Method.*—The various steps having been investigated, it now remained to test the method as a whole. A number of blank experiments on various amounts of lead-free distilled water was made in the first place. As expected, a very small amount of lead was found in every case, the sum of the gains exceeding the combined negative errors. The actual results obtained were as follows:—

TABLE VI.

Blank Experiments on Complete Method, Using Lead-free Distilled Water, S.C.P. Porcelain Dishes.

No.	Distilled water taken (litres).	Lead found.
1	2.5	0.015
2	2.5	0.025
3	3.5	0.030
4	5.0	0.030
5	2.5	0.035

The blank correction varies from 0.015 to 0.035 mg., with an average of approximately 0.025 mg. This represents approximately one part of lead in 100,000,000 parts of water taken. In another series of experiments 2.5 litres of lead-free water were evaporated after the addition of various amounts of lead. The series was carried through as described above, with the following results :—

TABLE VII.

No.	Distilled water (litres).	Lead added (mgm.)	Total lead found (mgm.)	Lead from blank.	Net lead found.
1	2.5	0.025	0.050	0.035	0.015
2	2.5	0.050	0.080	0.025	0.055
3	2.5	0.100	0.125	0.025	0.100
4	2.5	0.200	0.200	0.025	0.175

If, therefore, a sample should contain about 0.01 mg. per litre, and 2.5 litres be taken for analysis, the total lead found would be about 0.05 mg., of which about 0.025 would be deducted for the blank. In such a case the experiment should be repeated on not less than 5 litres of sample, when the total amount of lead found would be 0.08 mg., of which about 0.03 would represent the blank correction. It is possible, therefore, to detect and estimate lead even when present to the extent of only one part in 100,000,000.

ORGANIC MATTER PRESENT.

The next case to be considered is that in which organic substances are present in appreciable amounts. Special treatment will probably be required for the different types of substances to be examined, but the general method of procedure should be broadly applicable to most cases. The investigation was confined to the method of determining lead in urine. The chief difficulties which presented themselves were connected with the complete destruction of the organic matter. In almost all other respects the problem is similar to the determination of lead in water.

Methods of Analysis.—Various methods for eliminating organic matter were tried out, including the following :—

(*a*) Evaporation and treatment with hydrochloric acid and potassium chlorate (Fresenius and Babo's method).

(*b*) Electrolytic oxidation methods.

(*c*) Evaporation and treatment with concentrated nitric acid.

Treatment with concentrated nitric acid was found to be more satisfactory than the others, possessing the following advantages:—

1. The destruction of the organic matter is complete.
2. The process of oxidation is rapid.
3. A moderate amount of only one reagent (nitric acid) is required.
4. The reagent can be purified immediately before use by simple re-distillation.
5. The excess of the reagent and its salts may be entirely eliminated by evaporation and gentle ignition (at 500° C.)
6. The destruction of the organic matter can be effected without appreciable loss of lead.

Outline of Method.—One litre of urine is evaporated nearly to dryness with about 8 % of its weight of concentrated nitric acid. The mixture is then gradually heated to about 500° C. in a muffle, to drive off the excess of nitric acid, to oxidize the organic matter, and finally to decompose nitrates.

The white residue is dissolved in dilute hydrochloric acid, the amount of free acid being finally adjusted to exactly 2 cc. in excess, and the total volume to 250 cc. The lead and second-group metals are then separated as sulphides. The lead sulphide is filtered and dissolved in nitric acid; the lead is separated as lead sulphate, the latter being then dissolved in ammonium acetate and determined colorimetrically.

In order to test the method of analysis, a series of experiments was made upon a bulk sample of urine. Known amounts of lead were added to 1 litre portions of the sample, and the lead estimated by the above method. It was found to be difficult to obtain perfectly lead-free samples even in Melbourne. The bulk sample used contained only a minute amount of lead, which has been corrected for in the following results:—

Experiment No.	Lead added (mg.)	Lead found.	Percentage recovery.
1	0.10	0.090	90
2	0.20	0.185	92.5
3	0.30	0.285	95

The electrolytic method was also investigated and modified in some respects. Good results can be obtained with the improved method, but there is still some uncertainty with regard to the completeness of deposition of lead on the electrodes, and also the complete removal of the lead after deposition. This appears to be connected with the presence of suspended fatty matter, especially in pathological urine after evaporation. Organic matter is carried down with the lead deposited on the cathode, and renders the solution of the lead in nitric acid difficult. If the cathode is heated strongly to destroy the organic matter before the lead is completely removed, the latter alloys with the platinum and contaminates subsequent samples.

The investigation of the electrolytic method indicated that, as improved, it gave more satisfactory results, and it could no doubt be still further improved, but as the chemical method was found to be more satisfactory and more reliable no attempt was made to further develop the electrolytic method.

SUMMARY.

A method of determining minute amounts of lead in water and in urine has been investigated, and an analytical method for each has been developed in detail. The causes of error in the course of the analysis have been examined, and either eliminated or reduced to small known magnitude. The sensitiveness and reliability of the determination of lead have been considerably increased.

APPENDIX.

Determination of Minute Amounts of Lead.

General.

The determination demands the greatest care throughout, and calls for analytical training and manipulative skill of a high order. Each part of the apparatus must be tested, and only used if the total amount of lead introduced is of a very small order of magnitude. The containers should, whenever possible, be tested before collecting samples. If this cannot be done the container should be examined after transferring the sample into a lead-free bottle, and if the examination shows that lead may have been introduced into the sample from the container the sample should be rejected.

All filter papers must be tested and treated until lead-free before use in the analysis.

Reagents.

All reagents should be free from lead. Wherever possible they should be re-distilled before use, using lead-free glass for re-distilling and storing.

Reagents Required:—

Distilled water.

Re-distilled nitric acid.

Re-distilled hydrochloric acid, about 6N.

Re-distilled sulphuric acid. This is prepared by distilling pure sulphuric acid in a small resistance glass retort.

Re-distilled acetic acid.

Re-distilled ammonia. (Note.—The ammonia should yield a perfectly colourless solution when neutralized with pure acetic acid and boiled.)

Ammonium acetate solution (1 : 2).—This was prepared by neutralizing re-distilled acetic acid with re-distilled ammonia, and diluting the mixture with twice its own volume of pure water. This should be quite colourless, and remain so on boiling for some time.

Hydrogen sulphide.—Made by the action of (1 : 1) hydrochloric acid upon ferrous sulphide. The gas is passed through two wash bottles containing water after it leaves the generator.

Ammonium sulphide.—This is prepared by saturating re-distilled ammonia with hydrogen sulphide. This solution should be quite colourless, and *must be made up immediately before use.*

Re-distilled absolute alcohol.

Potassium cyanide solution.—A 10 % aqueous solution of pure potassium cyanide is required. It must be free from lead, and preferably free from traces of alkaline sulphide.

No. 1 standard lead acetate solution (stock).—1 cc = 0.0001 grm. lead. Prepared by dissolving 0.1463 grm. of pure lead sulphate in ammonium acetate solution and diluting to 1 litre. (Note.—This solution keeps for a considerable time.)

No. 2 standard lead acetate solution (dilute), 1 cc. = 0.00001 grm. lead. Prepared by diluting 100 cc. of No. 1 (stock) solution to 1000 cc. with pure water. (Note.—This solution does not keep well, and should be made up at least every day or two.)

BLANK EXPERIMENTS.

Blank experiments should always be carried out parallel with the analysis; the correction indicated by the blank should be small compared with the quantity of lead determined. As the extreme limit the correction should not be more than 50 % of the total amount of lead found, and for satisfactory work it should be much less than this.

The total error indicated by the blank should not exceed 0.025 mg. (the sum of the positive and negative errors). The quantity of sample taken for analyses should be such that the total lead found will be about 5 or 10 times this amount.

DETERMINATION OF LEAD IN WATER.

Filtration.—The volume of the water should be ascertained and the whole sample filtered, preferably by an automatic feeding device, and the clear filtrate and sediment treated separately, the lead found in each being calculated to the amount of sample used.

(1) *Evaporation.*—Take 2.5 to 5 litres of the filtered water, evaporate in a 10-in. porcelain basin (S.C.P.) to approximately 100 cc., neutralize

or make slightly acid with hydrochloric acid to decompose any calcium carbonate or alkaline salts, then add an excess of 2 cc. of the hydrochloric acid and continue the heating for another five minutes. The acidity must be carefully regulated or the precipitation with sulphuretted hydrogen will be unsatisfactory.

(2) *Separation of Second-Group Metals.*—Filter through an 11-cm. filter paper into a 300-cc. Erlenmeyer flask, wash the dish and filter paper well with hot distilled water. Cool, and make the solution up to a bulk of 250 cc. Fit the flask with a rubber stopper with two holes, through one of which a straight glass tube passes nearly to the bottom of the flask, the end of this tube being drawn out to a fine jet. Through the other hole is passed another glass tube bent at right angles, going through the stopper for a length of about half an inch. Connect up with the hydrogen sulphide apparatus and bubble a slow stream of the gas through the cold solution for one hour. Allow to stand overnight, when any precipitate will settle out. Filter through a 9-cm. filter paper, wash out the flask three times with a small quantity of cold hydrogen sulphide water, and then wash the filter paper three times with the same liquid.

(3) *Separation of Lead as Sulphate.*—Dissolve the precipitate of sulphides by dropping 2 cc. of hot 1 : 1 nitric acid from a pipette around the filter paper, followed by another 2 cc. of the same, catching the solution in the original Erlenmeyer flask. Wash six times with hot distilled water. Warm the solution in the flask and evaporate to about 20 cc., then transfer to a 50-cc. cylindrical beaker (non-alkali glass), washing out the flask three times with warm water. Evaporate quietly to about 5 cc. on the hot plate, then add 1 cc. sulphuric acid and take to strong fumes. Cool, and add 20 cc. cold water, then 10 cc. of alcohol ; mix well, and allow to stand overnight. Filter through a 9-cm. filter paper, washing out the beaker with a solution of 65 volumes of water, 32 volumes of absolute alcohol, and 3 volumes of sulphuric acid, then wash the filter paper three times with the same solution.

(4) *Colorimetric Determination of the Lead.*—Dissolve any precipitate off the filter paper by dropping 5 cc. of hot (1 : 2) ammonium acetate solution from a pipette around the filter paper, followed by another 5 cc. of the same reagent, catching the solution in the original 50-cc. beaker. Wash six times with hot water. Cool and Nesslerize, using

a standard lead-acetate solution, 1 cc. = 0.00001 grm. lead. The Nesslerizing is carried out in the following manner:—Transfer the assay solution to a 50-cc. Nessler tube, add 1 cc. of a 10% potassium cyanide solution, 1 cc. ammonium hydroxide, and 6 drops of freshly-prepared ammonium sulphide. Make up to the 50-cc. mark and mix well. This assay solution is compared with a solution made up as follows:—In another Nessler tube take 10 cc. of the (1 : 2) ammonium acetate solution, 1 cc. of the 10% potassium cyanide solution, 1 cc. ammonium hydroxide, and 6 drops of ammonium sulphide. Make up to about 45 cc. and mix well. This solution must be quite colourless. Add to it the standard lead-acetate solution, stirring after such addition until the colour matches that of the assay, when both tubes are placed in a colorimeter. It is advisable to arrange the strength of the assay solution so that not more than 8 cc. of the standard lead solution will be required for Nesslerizing. If much lead sulphate precipitate is noticed after the addition of water and alcohol, the solution in ammonium acetate must be made up to a definite volume, and an aliquot part taken for Nesslerizing, so that not more than 8 cc. of standard solution will be used in the comparison. In this case use the same proportion of (1 : 2) ammonium acetate for making up the comparison solution as is contained in the aliquot part of the assay solution.

Method of Treating Sediment.—The sediment is treated on the filter paper with 10 cc. of hot concentrated hydrochloric acid by running it from a pipette around the filter paper. This is followed by another 10 cc. of the hot hydrochloric acid. The solution is allowed to run into the bottle which contained the original water sample, the filter paper being washed six times with hot distilled water, the solution washed around the bottle several times, and then transferred to a 300-cc. beaker (non-alkali glass), the bottle being rinsed out three times with hot water, and the washings added to the main solution. The solution is evaporated just to dryness, when 2 cc. hydrochloric acid and 10 cc. water are added. The solution is warmed and filtered through a 9-cm. filter paper into a 300-cc. Erlenmeyer flask, cooled, and made up to a volume of 250 cc. From this stage the method is carried on in the same manner as for waters. (See (2) Separation of Second-Group Metals.)

DETERMINATION OF LEAD IN URINE.

(1) *Evaporation of the Urine.*—Place 500 cc. of the sample in a 7-in. porcelain basin (S.C.P. ware), add 50 cc. of nitric acid, and evaporate on the hot plate, gradually adding another 500 cc. of the sample, making 1 litre in all. (If the urine contains much sediment more nitric acid is necessary.) Continue the evaporation until about 30 cc. are left.

(2) *Destruction of Organic Matter.*—Transfer to a silica dish (about 3½ in. in diameter), cleaning out the porcelain basin with 10 cc. nitric acid, and finally washing it out with distilled water. Allow the contents of the dish to evaporate slowly on the hot plate to avoid loss by spraying. Continue the evaporation to dryness, being careful to avoid overheating, which causes the mass to fume strongly, and possibly to deflagrate. When dry, place the dish in a small muffle, preferably electrically heated, and heat until fuming ceases and the mass becomes charred, proceeding very cautiously, to prevent deflagration, especially at first. Gradually increase the temperature by pushing the dish further into the muffle until the carbon burns off quietly and the mass becomes white. Heat to between 450° and 500° C. until red fumes cease to be given off, usually in about 20 minutes. If the nitrates present are not completely decomposed at this stage the analysis will have to be rejected.

(3) *Separation of Second-Group Metals.*—Cool, add hot water until the dish is about two-thirds full; heat to boiling on hot plate, break up lumps with a glass rod, and carefully add hydrochloric acid until the solution is clear and either neutral or very slightly acid. Then add exactly 2 cc. hydrochloric acid in excess. Special attention must be given to the acidity of the solution at this stage. The white residue after ignition is usually alkaline, and must be carefully neutralized, then the required excess of acid added. Filter off any small residue of silica through a 9-cm. filter paper, wash well with hot water, catching the filtrate in a 300-cc. Erlenmeyer flask. Cool, and make up bulk to 250 cc. Then proceed as in the examination of water ((2) Separation of Second-Group Metals).

Note.—If much sulphur is precipitated during the treatment with sulphuretted hydrogen it indicates that all the nitrates have not been decomposed owing to insufficient heating in the muffle. In this case the analysis should be rejected.

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DESCRIPTION OF NEW PLANT AT SOUTH MINE, BROKEN HILL.

BY W. E. WAINWRIGHT AND J. C. CUNNINGHAM.

ORE TONNAGE TREATED.

JUST prior to the war the Broken Hill South Ltd. raised, on the average, 6628 tons of ore per week, all of which was crushed and treated in the 4-section gravity mill and the slime flotation plant, for the recovery of lead concentrate carrying silver. The sandy residues from that treatment were railed to the treatment plant of the Amalgamated Zinc (De Bavay's) Ltd. for the recovery of zinc concentrate by flotation, on the joint account of both companies. Subsequent to that—since 1916—approximately 1000 tons of old dump slime were also treated weekly for the recovery of lead and silver as slime-lead concentrate.

PLANT CAPACITY.

Under this programme the Babcock and Wilcox boiler plant of 8 boilers was taxed to such an extent as to call for the installation of two additional boilers, each of 2690 sq. ft. of heating surface and 55 sq. ft. chain-grade area.

The electric generators and the air compressors of the old power-plant were also loaded to their maximum capacity.

In view of the fact that the old power-plant had been added to from time to time since 1901, and that further extension was not possible, and as it was not, moreover, an economical arrangement, the whole question of power generation was reconsidered.

The considerations that determined the installation of entirely new plant were as follow :—

(1) The need for more compressed air for underground work and more electric current for the extension of the slime-flotation plant for the recovery of zinc, as well as lead, as slime concentrates. Provision of additional power was also deemed advisable for the

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treatment of the sand residues on the mine, at the termination of the contract with the Amalgamated Zinc (De Bavay's) Ltd.

(2) The desirability of more economical power generators in order to reduce demand for steam from boilers.

(3) The reduction in cost of running and maintenance of one (or two) large generators compared with that of the several old and small units.

(4) The advantage that would accrue—both in the boilers and the generating units—by having a condensate feed water, thus eliminating the priming which existed in the boilers, and which had the effect of keeping down the temperature obtainable in the boiler superheaters, choking the superheater boxes with a fine aluminous lime deposit. This deposit was also passed through the steam mains and engine cylinders, also the turbine blading of the exhaust turbo-alternator, causing undue wear and fouling of the former and choking up of the latter.

(5) The necessity for making all modifications of power-plant without interfering with the running of the old plant.

(6) The fact that a cooling tower existed for the exhaust steam turbine, which, with some modification, could be made to serve the new power-plant.

PLANT SELECTION.

Broken Hill has suffered through indecision in the past to instal a central power-plant such as would have reduced the cost of generating power, as well as the total expenditure for the aggregate requirements of the industry and district. For the successful carrying-on of mining and treatment operations, the supply of power must be continuous and reliable, and not subject to breakdown stoppages. On that account it is essential to have stand-by units, wherever repairs and overhauls of any portion of the plant require an appreciable time for their proper execution.

In connection with the South mine power-plant, it was early decided that all non-condensing engines and long steam mains should be eliminated as much as possible. This involved the electric driving of the whole of the concentrating mill and some of the air-compressing plant.

In view of the fact that 10 Babcock and Wilcox boilers were already installed and in good condition, the consideration of gas engines was put aside. Again, existing electric plant was three-phase, alternating, 40-cycle, and so the power-plant selected was high-pressure steam turbo-alternators of 3000 kw., 600 volts, at .8 power factor, or 3750 k.v.a., that being the size which the various treatment-plant extensions were estimtaed to require.

Since that decision was arrived at, shorter hours have come into force, which must reduce the output of ore per week. This must naturally reduce the weekly power output.

When the present depression has passed, the plant described hereafter can be utilized to its full capacity.

BOILERS.

Ten Babcock & Wilcox boilers, each of 2690 sq. ft., and each fitted with chain-grate stokers having 55 sq. ft. of grate area, built in 5 batteries of two each, comprise the boiler equipment. At least one battery of boilers is always out of commission for cleaning and repair purposes.

The stoker gear is driven by a small Belliss engine, controlled by an Auld's automatic steam-pressure regulator, which speeds the engine with any slight fall of the working pressure below 150 lb. per sq. in.

The draught is given by one of duplicate 108-in. induced draught fans, with 5-ft. diam. stacks, operated by Belliss engines at 220 maximum revolutions. The speed of the engine and direct-coupled fan is also controlled by an Auld's automatic steam-pressure regulator.

By the use of these separate regulators the proportioning of draught to coal supply can be readily adjusted to give the best condition of fires, but that adjustment is rendered comparatively easy by virtue of the relatively-uniform load that prevails during the working week.

The draught in each boiler is made the same by setting the movable dampers at the back of each boiler so that there are uniform fires in all boilers.

The uniformity of steam pressure obtained by this automatic control of coal and draught is shown by the pressure-gauge record (fig. 1).

The coal supply is obtained from a 2500-ton storage bin, running parallel with the front of the boilers. The coal is drawn out through chutes into trucks, weighed on small platform bridges, crushed in a No. 3 Gates breaker, and elevated to a flat-rubber belt conveyor, which distributes the coal into 5-ton concrete-lined steel hoppers, one of which is placed immediately above the feeding hopper of each boiler.

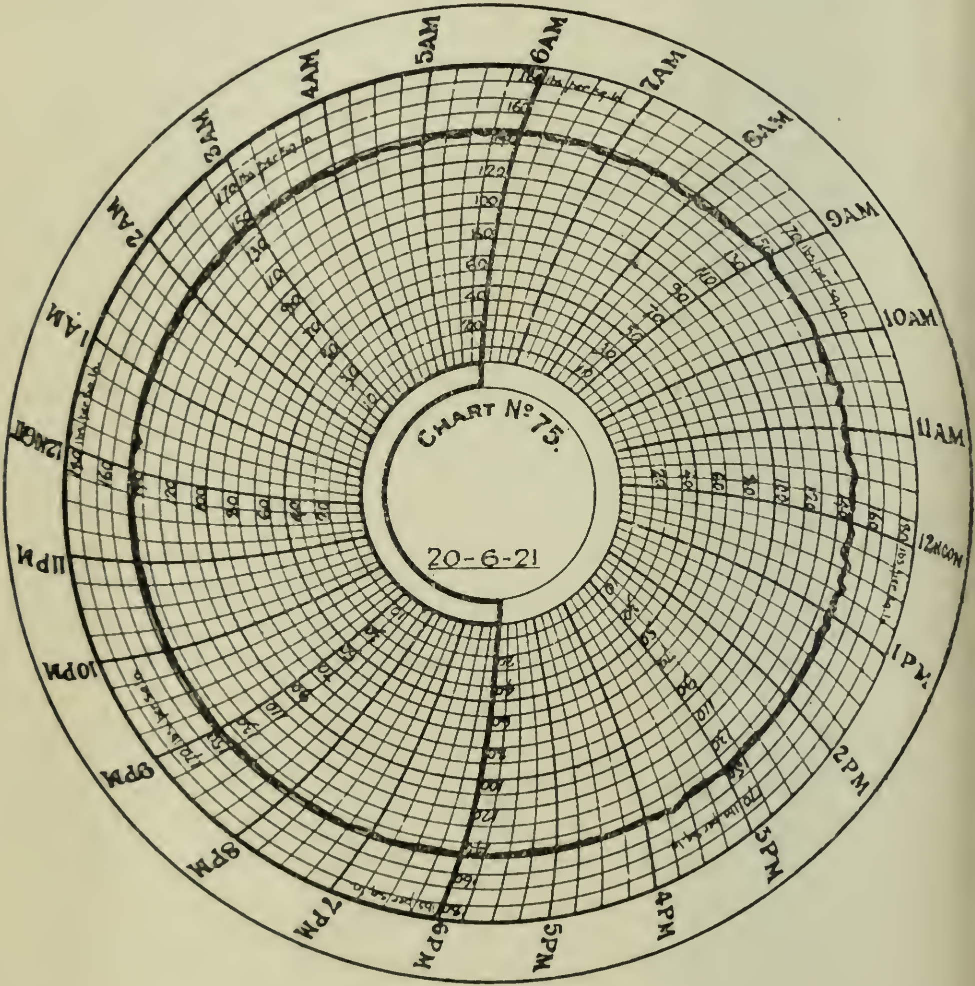

Fig. 1.
Steam Pressure Recorder Chart.

The steam generated is passed through large superheaters supplied by Messrs. Babcock & Wilcox, and which are built into the boilers. With the relatively small amount of softened make-up water which is added to the condensate returned by the generating units, in order to replace the steam exhausted to atmosphere by the main hoisting (or winding) engine and the fan and stoker engines, the boilers do not now prime as they used to do when the feed was practically all softened water. In consequence, the superheat temperature is now about 520° F. at the boilers on the average, and reaches 580° F. maximum.

STEAM MAINS.

The site for the new power-generator building was chosen as close to the boilers as possible, a diagonal through the boiler plant being in line with a diagonal through the power-generating building. On this account a longer steam main occurred than was desirable, and, in consequence, a number of experiments were made to determine which of the many materials offering would give the best insulation. After testing cellular slabs, asbestos, and other wet compositions, slag (or mineral) wool was finally selected on account of the low temperaures obtained on the outside. The thickness employed was 3½ in., and the manner of application as per Plate I. This construction supports a casing of galvanized iron at a uniform distance from the body of the pipe. The iron is held on by hoop-iron straps, immediately underneath which are light iron rings in halves, and lapped and bolted together. These rings are in turn held in correct position by two or three fibro-asbestos radial strips, which are bolted to the upper half-ring only in the case of a horizontal pipe. The iron straps are not tightened until the casing has been filled through a wide slot space running the full length of the casing. After the casing has been filled a sheet of galvanized iron, wide enough to cover the distance between the edges of the casing, and which has already been placed under the straps, is drifted over so as to cover the space and keep rain from getting into the casing.

The casing over the flanges is larger in diameter than that over the pipe, and the length is so arranged that the joint bolts can be removed without removing the semi-circular fibro-asbestos rings which form the ends of the pipe casing and the support for the galvanized-iron flange-casing.

The temperature of steam when it leaves the superheaters at the boilers averages about 520° F., and when it reaches the stop valve of the 3000 kw. steam turbo-alternators it has fallen to 500° F. Anchors on the steam main are provided at 3 points, and all expansion away from these points is taken care of by the bends and long lengths of pipe that intervene, all of which are supported from swinging hangers, suspended from suitable structures overhead. The class of joint used on the main is made by cutting rings of brass wire, wove, 16-mesh, 25-gauge, of sufficient width to cover the joint surface between the bore of pipe and inside edge of bolt holes. The ring then has two rows of duplex lead wire laced through the wove. Dixon's jointing compound is then applied on the ring. The function of the lead wire is to prevent the jointing compound from blowing out of the wove under pressure.

NEW POWER GENERATORS.

The building required for the housing of the new plant has been completed generally in accordance with the proposed arrangement set out in Plates II. and III. The basement is 16 ft. 9 in. below the operating floor, which is a few inches above the ground level around the building.

The basement, basement walls, and operating floor are all of concrete of the proportion of 5 stone, 3 sand, and 1 cement. The main walls are of brick set in cement-lime compo.

The building measures 136 ft. long by 63 ft. wide, the height from basement to the plate carrying the roof principals being 49 ft. 9 in., and from basement to apex of gable 69 ft.

The ventilation of the building is effected by means of two large openings in the apex of the roof, which, in wet weather, are closed by two sliding covers, operated simultaneously by a wire rope on small hand winches set up on uprights in the ground at each end of the building. One winch opens and the other closes the openings. When these are closed on account of weather, the ventilation occurs through two large doors, one at each end of the building.

The roof is of corrugated iron, and, being unlined, the under side is painted a pale French grey. The walls and foundations are limewashed throughout to give good illumination. Portion of the floor is of reinforced concrete; but where any auxiliaries occur in the basement the floor overhead is of portable, marine-grid type, in order to make all machinery in the building accessible to the 20-ton electric crab, which is traversed longitudinally and transversely by hand. The 14-in. x 6-in. steel joists which form the runway of the crane are carried on brick buttresses formed on the main wall of the building.

The machinery installed inside the building comprises the following :—

No. 1 set.—400-kw. Belliss engine alternator.

No. 2 set.—3000-kw. Fraser and Chalmers Vickers high-pressure steam turbo-alternator set, complete, with Allen kinetic condensing plant.

No. 3 set.—3000-kw. Fraser and Chalmers Vickers high-pressure steam turbo-alternator set, complete, with Allen kinetic condensing plant.

No. 4 set.—1000 b.h.p. Belliss turbine-driven, geared, reciprocating air compressor, complete, with Belliss kinetic condensing plant. (Volume compressed, 5000 cub. ft. free air per min. to 90 lb. pressure.)

2 59-kw. motor-driven exciters, for Nos. 2 and 3 sets, each of 357 amp. and 140 maximum volts.

2 83-in. Heenan and Froude air-washers, for air supply to alternator fans

1 60-in. Heenan and Froude air-washer, for turbo-compressor.

3 Precision water meters, for the measurement of condensate from the condensers of the Nos. 2, 3 and 4 sets, are set on the main operating floor.

1 feed-water storage tank, to receive the condensate from the meters, and to which softened water is added automatically through a float valve in order to make up the loss of steam that occurs from steam main drains, winding engine, and other engine exhausts to atmosphere.

2 Weir steam turbine-driven, single-stage, centrifugal feed-pumps, for automatically delivering feed water to boilers; each is capable of delivering 100,000 lb. of feed water per hour.

2 motor-driven, two-stage, centrifugal pumps, for raising cooled water for circulation through various oil coolers and air-compressor cylinder jackets and intercoolers.

1 polished slate switchboard, by the American General Electric Co., for the operation of the main and feeder switches, etc., as described hereafter.

1 complete switch equipment, in special switch room on the basement, all of which is operated electrically from the switchboard above.

There is also a cooling water flume (or duct), measuring 5 ft. x 6 ft. deep, and extending nearly the length of the building. This is maintained full by a 24-in. direct-coupled, motor-driven, twin centrifugal pump through a 24-in. main, on the discharge end of which a float-controlled, balanced valve does the regulating. The pump which supplies the duct is located at the side of the cooling tower, and has a hydraulic head on the suction side, on account of the top of suction sump being higher than the pump.

Cooling Tower.

The cooling tower is of Cunningham's patent elevated, louvred-bottom type, and, as illustrated in Plates VII. and VIII. fig 1, the method of spraying the water is by centrifugal saucer nozzles. The pressure in the main which runs along one side of the cooling tower and distributes the water to the sprays is about 8 lb. at the level of the sprays, but this is varied to suit the weather conditions. For instance, in windy weather the number of sprays in operation is increased so as to reduce the working head and so increase the size of drops produced by the nozzles, thus reducing the mechanical loss by wind.

In hot summer weather, with the dry-bulb thermometer ranging up to 105° F. and the wet bulb up to 70° F., the increased absorbing capacity of the air for water, or, more technically, the increased vapour pressure of water at about 100° causes considerable additional loss by evaporation. This is more readily understood when it is pointed out that in the usual chimney type of tower the temperature of the cooled water in the middle of a summer day may approximate to the dry-bulb temperature of the air, whereas in a tower of the elevated, louvred-bottom type, here described, there is a freer access of air, and, consequently, the cooled water can more nearly approach the wet-bulb temperature.

The inlet temperature to the cooling tower on hot days is always below the dry-bulb temperature, so that, obviously, there must be a greater loss of water by evaporation compared with the condition that obtains in the winter, when both the inlet to and outlet from the tower are higher than the dry-bulb temperature of the air.

When the plant is in continuous and steady operation, some interesting data will be obtainable on the problem of cooling water for condensing purposes.

Air Compressors.

In addition to the turbine-geared compressor in the new plant, 2 motor-driven air compressors are housed in the old power-plant building. These have been made by converting 2 Belliss triple-expansion, 400-kw. engine alternators of 343 rev., as follows:—

The 3 steam cylinders were replaced by air cylinders, 2 of which are low pressure and 1 high pressure, with an intercooler between the two stages. Each compressor is driven by a 440 b.h.p. slip-ring induction motor, and runs at 260 rev., with an intake of 2500 cub. ft. per minute.

All compressors are fitted with an automatic control, so arranged that when the pressure rises to any pre-determined extent the air supply to the low-pressure cylinders is cut off, and when it drops about 2 or 3 lb. the air is re-admitted.

With the mine running on a small output, the amount of compressed air required for all purposes—both underground and on the surface—can be readily supplied by one motor-driven compressor.

In this way a more economical load can be built up for one 3000-kw. turbo-alternator unit, which develops all power required, excepting only the steam winder on the No. 1 shaft, the induced draught fan engine, the stoker engine, and the steam-driven service and fire pumps.

ELECTRICAL EQUIPMENT.

Control Board. The switchboard providing the control for the generation and distribution of electrical energy is built up of 18 panels of enamelled black slate, and, from left to right, are arranged as follow:—

- 4 exciter panels
- 1 voltage regulator panel
- 2 main feeder panels
- 3 generator panels
- 1 recording ammeter and earth-leak detector panel
- 3 main feeder panels
- 4 sub-feeder panels

with direct current voltmeters and synchronism indicators on swinging brackets at the left and right ends of the board respectively.

The exciter panels are provided with ammeters, rheostat hand-wheels, voltmeter plug and double-throw switches, so that any exciter may be coupled to either of the two d.c. busses provided. This allows one of the smaller exciters to be used for operation of the switch gear, and excitation of various special magnets on the mine to be operated independent of the 50-kw. exciters which supply the fields of the 3000-kw. turbo-alternators. The Tirrill automatic voltage regulator operates on the shunt rheostat of the 50-kw.

exciters to maintain a constant a.c. buss pressure of 580 volts, and provides for variation of this pressure, if necessary, over a small range, plus or minus.

The main feeder panels are equipped with ammeter, 3-way ammeter switch, voltmeter, synchronizing plug, pull buttons (with red and green indicator lamps for switch operation), and integrating Watthour meters.

The generator panels are equipped with a.c. ammeters, 3-way ammeter switch, voltmeter, indicating Wattmeter, synchronizing plug, d.c. ammeter, generator field, and discharge switch. Pull buttons (with indicating lamps) are provided for main switch operation, and pull buttons to operate the reversible motors on the turbine steam governor control and the main field rheostat. The 3-way a.c. ammeter switches on feeder and generator panels are provided to connect the meter in with any one phase of the circuit, as a check on possible unbalanced loading or fault.

The main a.c. switch gear and bus bars are located in a fireproof concrete room in the basement, situated directly under the control board, so that there are no a.c. bars behind the control board, except at the extreme right-hand end, where one main feeder feeds sub-busses for the 4 sub-feeder panels.

The recording ammeter provides for the taking of permanent chart records of the load conditions of any generator or feeder, by connecting it in series with the meters of the panel controlling the circuit of which record is desired.

The electrostatic earth-detector gives warning of the occurrence of any slight leak, so that it may be remedied before a second such leak on another phase develops a short-circuit.

Two sub-feeder panels carry 800 amp. oil switches, 2 to each panel, directly bolted to the back, and operated by hand lever from the front.

Meters on these circuits consist of ammeters and integrating Watthour meters. No. 3 sub-feeder panel controls the whole of the mine lighting, and is provided with a double-throw, interlocked oil switch, which takes its feed from the South mine sub-buss normally, but, in emergency, can supply its load from the Central mine feeder panel, located alongside. The lighting panel is provided with integrating Watthour meter, and also ammeters in each phase, so that the connecting of single-phase transformers used for lighting, etc., may be adjusted to keep a balanced load as close as possible. Double-throw switches are provided on this panel, controlling 10 k.v.a. and 15 k.v.a. transformers, and manipulation of these, changes these transformers from one phase to another, to enable close balance of load to be obtained.

No. 4 sub-feeder panel at the extreme right-hand end of the control board takes its feed from the sub-buss, and forms a feeder to link with the Central mine power plant, with which power is exchanged during times of light load or emergency. This panel carries an a.c. ammeter, voltmeter, central zero indicating Wattmeter, and two integrating Watthour meters.

Switch Room.—Mounted in the basement switch room there are 2 5000-amp. oil switches for the main generators, 6 2000-amp. oil switches for the 5 feeders, and 1 400-kw. Belliss G.E. generator.

These switches are all solenoid operated through relays, operated by the pull buttons on their respective panels of the control board overhead, d.c. at 120 volts for the magnets being provided by the 16-kw. exciter running on the lower d.c. buss, and protected by air circuit-breaker mounted below the voltage regulator on the control board.

The switches are mounted on $1\frac{1}{4}$-in. pipe framework, which serves to carry the overhead copper bus-bars of 6-sq. in. section per phase. This same framework also serves to carry the main field rheostat at the extreme ends of the room, high up, where their heat loss is carried away by the air without trouble.

Bus-bar type current transformers are provided on all circuits to operate the meters, and tripping relays on the control board. The generators are protected by overload inverse time-limit relays, with the addition of a definite time limit to prevent the generator switches opening instantaneously under short circuit.

The feeder relays are plain, overload, inverse time-limit, thus securing selective action between feeders and generators in the event of a short-circuit on a feeder outside the plant.

The 400-kw. generator is provided with a "loop buss" to the sub-buss on the control floor, so that the whole of the main busses and switches may be isolated at light load periods for necessary examination or repair.

All outgoing feeders are of 4-in. x $\frac{1}{4}$-in. or 4-in. x $\frac{1}{2}$-in. bus-bar copper, and are carried outside the plant in fireproof-lined ducts.

In the case of the main mill feeder, this duct extends to the No. 1 motor control house, from which point suspended cables continue to the No. 2 motor control house at the flotation plant. Present load conditions on this feeder give a consumption of about 6,000,000 units per annum, which will be increased considerably when productive operations on a normal scale are resumed.

The temperatures of the generator windings are indicated by instruments fitted on a special panel on the operating floor mounted forward of the main control board.

By means of Precision d.c. ammeter and voltmeter, the resistance of the rotor windings may be calculated while the machine is under load, and by referring this to the resistance at some known temperature, the temperature while running is obtained continuously. Thermo couples bedded in the stator windings indicate the hot spot temperature of the stator.

Compensated distance thermometers indicate the inlet and outlet air temperatures.

Motor Control Board.--All of the power plant motors being of the squirrel-cage type, their starting panels are grouped on the operating floor along the western side as an extension of the main control board, iron-clad emergency switches for stopping and signal bell pushes being provided at each motor.

The control gear of all motors for boiler plant, workshops, and sawmill is carried on the same board, which has a total of 44 panels.

Each motor panel is provided with an oil-switch overload protection, a lever switch in the starting circuit, an ammeter, and signal drop-shutter with indicating lamp.

An audible signal is provided for code ringing.

Two starting compensators *only* are used for these 44 panels, the operation of starting a motor being as follows :—The lever starting-switch is closed, which connects the motor to a set of dead busses. These busses are energized by throwing either compensator to the starting position ; the acceleration of the motor is indicated by ammeter, and, when about completed, the compensator is pulled to the running position, giving the motor full voltage. The motor oil-switch is now closed, thus providing a parallel circuit to the compensator, which latter is now tripped, and the starting switch pulled out, leaving the motor running on its circuit breaker with its overload protection and ammeter to indicate actual load.

AIR WASHERS FOR ALTERNATORS.

The experience with the Heenan and Froude air washers has been good, although shortly after starting the first set it was found that the eliminators were allowing particles of water to pass into the duct and alternator.

Investigation showed that the water being used was causing incrustations to form on the rotating nest of wet plates, and so causing a greater quantity of water to be lifted from the tank. This happened notwithstanding that the minimum concentration of salts in the trough water was aimed at by having a continual overflow and an automatic ball valve inflow.

Evidently, notwithstanding these precautions, the surfaces of the galvanized plates became coated. The apparent remedy was purer water, and all trouble has disappeared since the filters were scraped and the washer water was drawn from the discharge from the condensate meters.

HEAT ECONOMIES.

In arranging the exhaust steam mains, the following requirements have been catered for:—

(1) Good insulation.
(2) Use of as much steam as possible for heating feed water.
(3) Steam for heating men's change-houses and foremen's change-rooms.
(4) Heating of water during water-softening process.
(5) Keeping all oily exhaust steam separate from steam free from oil.
(6) Use of that portion of the steam which is free from oil and in excess of that required for heating feed water in the low-pressure blading of the 3000-kw. turbines.

The steam free from oil is applied through injector nozzles for the heating of feed water, and oily exhaust is applied through tubular surface contact heaters, in which the exhausts from the winding engine, fan engine, and stoker engine are utilized. It is also used for heating change-houses and the water in process of softening.

A considerable proportion of the winding-engine exhaust obviously escapes to atmosphere.

During the afternoon and the night shifts, when the steam winder is not in operation, exhaust steam from the turbine feed pumps is used for heating the No. 1 change-house, etc.

POWER-PLANT RECORDS.

The following information has been culled from the power-plant records, and is indicative of results obtained during summer and winter conditions on the 3000-kw. sets :—

	25/1/21.	8/6/21.
Steam pressure (lb. per sq. in.)	146	146
Steam temperature at boilers, ° F. ..	—	520
Steam temperature at turbine stop valve, ° F.	468	500
Absolute condenser pressure in inches of mercury	2.02	1.75
Average total condensed steam (lb. per hour), including Terry turbine driving air pump	20,500	26,500
Average net output (in kilowatts per hour) after deducting power used for excitation and driving auxiliaries	1,370	1,440
Average lb. steam per kw. hour net output	No. 3 set, 14.95	No. 2 set, 18.4
Average temperature of water from cooling tower	82	67
Average temperature of water to cooling tower	95	76
Maximum dry-bulb temperature of air (° F.)	108.5	56.5
Maximum wet-bulb temperature of air (° F.)	70.5	55
Excitation amperage	152	175
,, voltage	105	105
Boiler evaporation—lb. of water per lb. of coal, at 150 lb. pressure and 500° F. superheat	6.05 (Bad coal)	7.3
Temperature of condensed steam from kinetic tank (° F.)	114	93

	25/1/21.	8/6/21.
Temperature of feed water to boilers (° F.)	227	226
Average temperature of engine-room air (° F.)	104	79
Temperature of air to alternators (° F.)—from	78–95	68–90
Water circulated through condenser (in gallons per hour)	270,000	270,000
Maximum induced draught at fan (in inches of water)	.9375	.9375
Maximum draught over fires in boilers	.16	.16

POWER-PLANT DIMENSIONS.

Length of building	136 ft.
Breadth of building	63 ft.
Height of floor above basement	16 ft. 9 in.
Height to traveller runaway from floor	24 ft. 6 in.
Height to wall-plate from floor	33 ft.
Height of basement to roof ridge	69 ft.
Total weight of 3000-kw. set and exciter	62 tons.
Total weight of condenser and auxiliaries for same	36.5 tons.
Total cooling surface of each condenser	7400 sq. ft.
Total steam requirements of turbo-alternators at 3000 kw.	45,000 lb. per hour.

TREATMENT PLANT.

During the construction of the new power-plant, and three months after the start of the strike in May, 1919, a disastrous fire occurred, which destroyed the whole of the No. 1 shaft poppet frame, the crude-ore bins, and intervening brace, and the whole of the ore-breaking section and mill bins.

Damage was also done to portion of the roll-crushing and jig sections.

The origin of the fire was undoubtedly incendiarism, and had it been of other origin the fire-fighting organization should have extinguished it, notwithstanding that the structures supporting the bins and breakers was of 10-in. x 10-in. oregon, pitched about 4-ft. centres.

Having decided that it was inadvisable to reconstruct the plant entirely to the old timber design, a new design, utilizing reinforced concrete and steel for the support of the bins and ore-breakers, was drawn up. The design adopted had the features described herein :—

Reinforced Concrete Structure.—The detailed design of reinforcement and walling was prepared by Mr. E. G. Stone in accordance with our general design, and the execution of the work was supervised by him through one of his foremen. This arrangement gave the advantage of satisfactory execution and expeditious completion of the work, the whole of which was completed in 29 weeks.

No. 1 *Shaft Poppet.*—This was reconstructed in 18-in. x 18-in. oregon timber, for expedition, so that, with the termination of the strike, ore-hauling might be resumed as early as possible.

Ore-Breakers.—In order that the ore hauled might be treated during the reconstruction of the ore-bins, ore-breakers, mill-bins, crushers and jigs, a temporary crushing station was erected, so that the crushed ore could be railed for treatment by other companies. As it turned out, the reconstructed bins and breakers were completed before hauling operations were resumed.

The lay-out of ore-breaker station provides two ore-breaking units, each comprising one crude-ore bin (for receiving the ore tippled from the trucks by a gravity tippler), one 30-in. x 18-in. Hadfield jaw-breaker, and two subsidiary No. 5D Gates gyratory breakers, to break the ore to pass a 1¾-in. slot.

Jaw-breakers, as usually manufactured, cannot be relied upon to run without considerable stoppages, due to heating of bearings. This has been overcome by re-designing the bearings and fitting this breaker with a flood lubrication arrangement, oil savers, oil filter and belt-driven gear pump.

A similar forced lubrication system has also been installed on the gyratory breakers. The capacity of each ore-breaking unit is about 150 tons per hour, the ore averaging 17 cub. ft. per ton.

The crushed ore drops into bins formed in the reinforced concrete structure supporting the breakers, and from these is fed on to an 18-in. troughed crude-ore conveyer system. The ore is raised by this system to a sampling plant, where 1 % of the total flow of ore is cut out every 70 seconds.

The remaining 99 % is raised to four crushed-ore bins feeding the four roll crushers. These bins, like the crude-ore bins, are of timber, but are supported on steel structures standing on a reinforced concrete understructure.

For the prevention of dust, the ore is watered underground, and the manganese wearing plates of the jaw-breaker are kept wet with water jets. In order to throw down the dust that is formed as the ore passes through the jaw-breaker, atomized water sprays are played on to the falling stream of ore discharged by the breaker.

The addition of water to the ore, however, increases its rilling angle, and the majority of gyratory breakers call for some modification to avoid the ore hanging up in the breaker, thus causing breakage of shafts, etc., and causing fine ore to get into the driving gear.

Ore Storage.—Damp, crushed ore in bins or in storage piles is liable to set if left undisturbed for a week. In addition to the crude and crushed ore-bins already referred to, storage bins are provided in the reinforced concrete structure under the 4 mill bins feeding the roll crushers, and a 2000-ton storage pile is also provided behind these bins, and all are filled from the conveyer. All of these storages are drawn from, as required, by the same conveyer system that conveys the ore to the storages or mill bins.

Roll Crushers.—This section is the same as was installed when the mill was built in 1908, and comprises 4 units, each having a capacity of 2000 tons per week. Each unit includes :—

1 roll feeder, for supplying the shaker.

1 perforated shaker, for washing out the 4 mm. ore and feeding the oversize to the rolls.

1 set 36-in. x 18-in. crushing rolls, with 1 flanged and 1 plain roll, and the usual back gears to cause both rolls to rotate together.

2 48-in. x 24-in. diam. 4-mm. trommels, for separating the oversize from the undersize.

1 Raff elevator, for returning the oversize to the rolls.

Jigs.—The jigs are May's duplex, built as one unit and running in parallel, and treat the undersize ore from the trommels, which is elevated and passed through a drag classifier before being fed to the jig. Each jig has 3 hutches, and is fitted with 4-mm. punched steel-plate sieves, which are bedded with 1¾-in. of ragging. This ragging is made by shearing 5–16-in. round rod into lengths about ¼ in. or 5–16 in. long.

The first hutch produces lead concentrates, which are drawn off through the bed of ragging into the inverted, pyramidal hutch underneath, and which has a continuous discharge. The second hutch is used as a safety margin and feed equalizer, and the middlings product produced is returned to the jig.

The third hutch has no screen, and simply discharges the tailings to the re-grinding section.

Re-grinding Section.– All re-grinding used to be done by grinding pans, and 2 of the 4 crushing sections are still so fitted. The products of the pans are treated on tables, the slime portion being treated in the slime-flotation section. The remaining 2 sections have each been fitted with one No. 64½ Marcy mill, with a view to improving the grinding and making the ground product more suitable for table and flotation treatment for the recovery of lead and zinc concentrates. These two sections have not yet been completed.

PLANT ILLUSTRATIONS AND DIAGRAMS.

Fig. 1.—Steam pressure recorder chart.
Plate I.—Steam main insulation.
,, II.—New power-house.
,, III.— ,, ,,
,, IV.– 3000-kw. alternators.
,, V.—General view of power-house.
,, VI., Fig 1.—Control board.
,, VI., Fig 2.—5000 cub. ft. compressor.
,, VII.—Cooling tower, exterior.
,, VIII., Fig. 1.– Cooling tower, interior.
,, VIII., Fig. 2.—Marcy mill section.
,, IX.—Old bin structure burned down.
,, X.—New reinforced concrete structure.

The engineering works covered by the above paper are mainly the design of J. C. Cunningham, while F. J. Mars is responsible for the selection, design and erection of the electrical equipment.

GHAM—ON NEW PLANT AT SOUTH MINE, BROKEN HILL. PLATE I.

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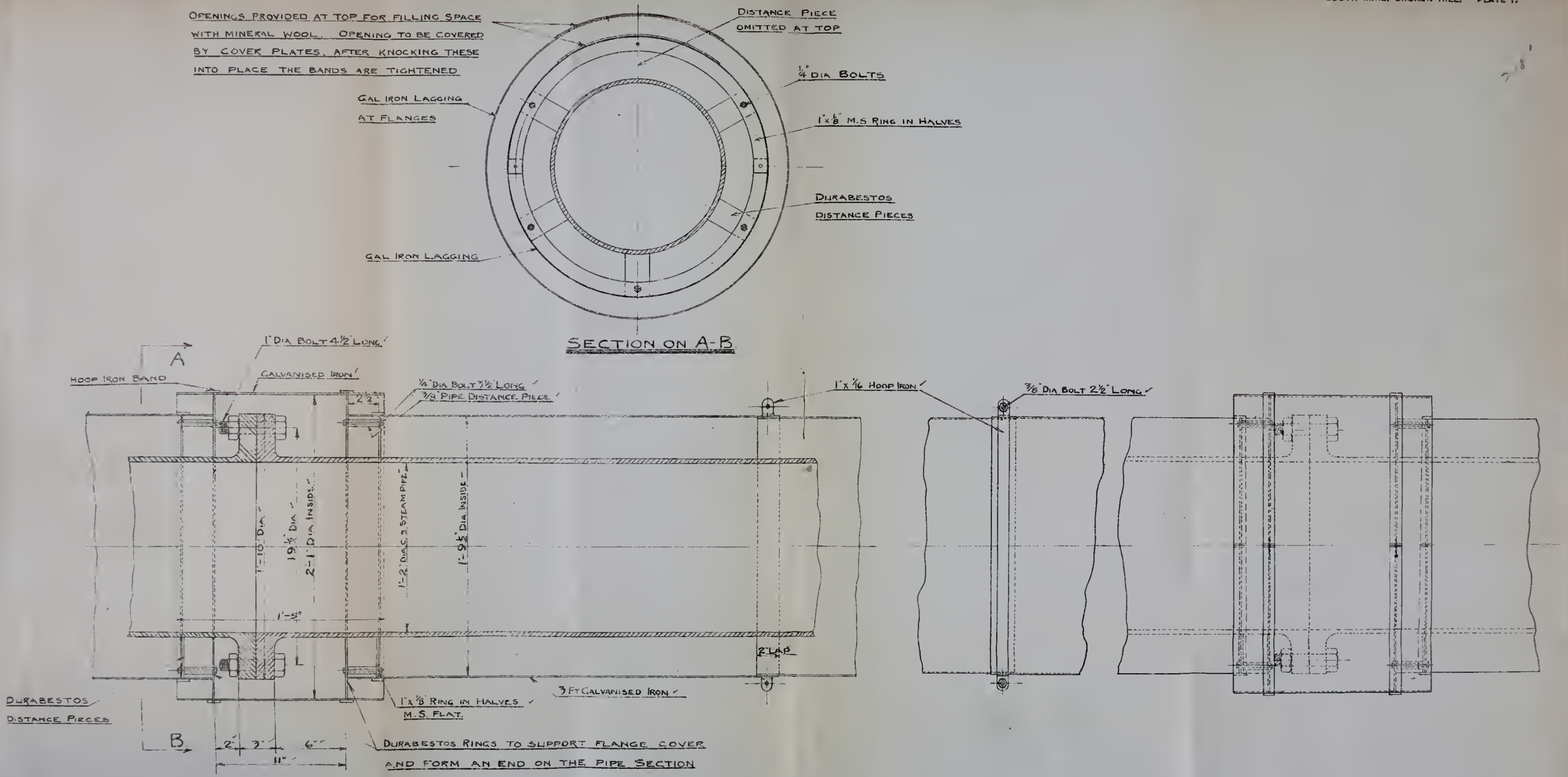
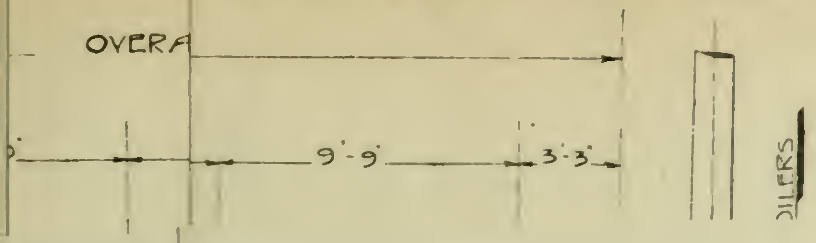
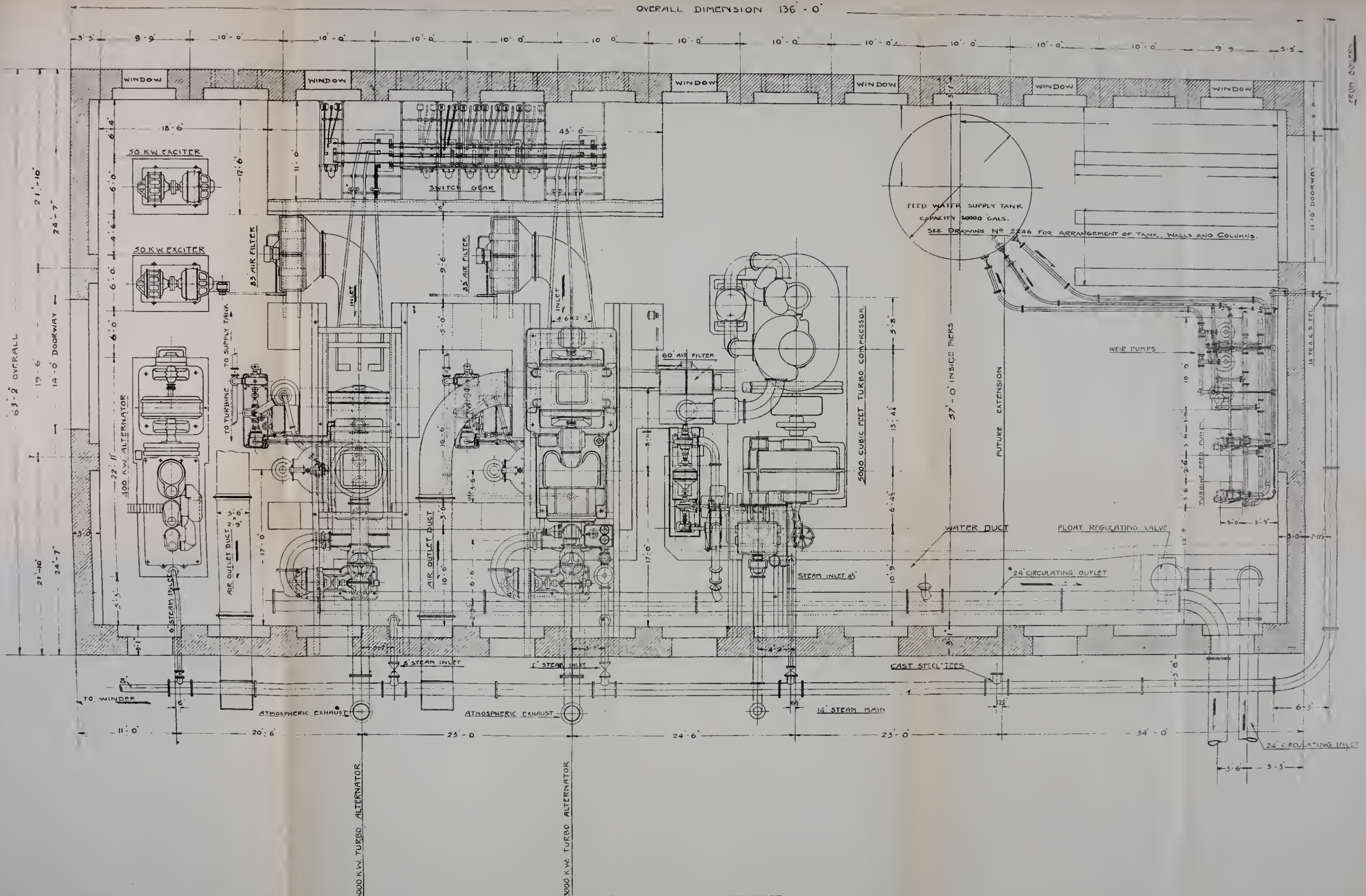

OPENINGS PROVIDED AT TOP FOR FILLING SPACE WITH MINERAL WOOL. OPENING TO BE COVERED BY COVER PLATES, AFTER KNOCKING THESE INTO PLACE THE BANDS ARE TIGHTENED
DISTANCE PIECE OMITTED AT TOP
¼" DIA BOLTS
GAL IRON LAGGING AT FLANGES
1"x⅛" M.S RING IN HALVES
DURABESTOS DISTANCE PIECES
GAL IRON LAGGING
SECTION ON A-B
1" DIA BOLT 4½" LONG
A
HOOP IRON BAND
GALVANISED IRON
¼" DIA BOLT 3½" LONG
⅜" PIPE DISTANCE PIECE
2½"
1"x1/16 HOOP IRON
⅜" DIA BOLT 2½" LONG
1'-10" DIA
19½" DIA
2'-1" DIA INSIDE
1'-2" DIA C.S. STEAM PIPE
1'-9½" DIA INSIDE
1'-5"
2" LAP
DURABESTOS DISTANCE PIECES
3 FT GALVANISED IRON
1"x⅛" RING IN HALVES M.S. FLAT.
B
2" 3" 6"
11"
DURABESTOS RINGS TO SUPPORT FLANGE COVER AND FORM AN END ON THE PIPE SECTION

SKETCH SHOWING METHOD OF APPLYING MINERAL WOOL FOR INSULATING PURPOSES.

SCALE—6 INS. = 1 FT.

NT AT SOUTH MINE, BROKEN HILL. PLATE II.





ARRANGEMENT OF NEW POWER PLANT.

SCALE—½ IN. = 1 FT.

HAM—ON NEW PLANT AT SOUTH MINE, BROKEN HILL. PLATE III.

3

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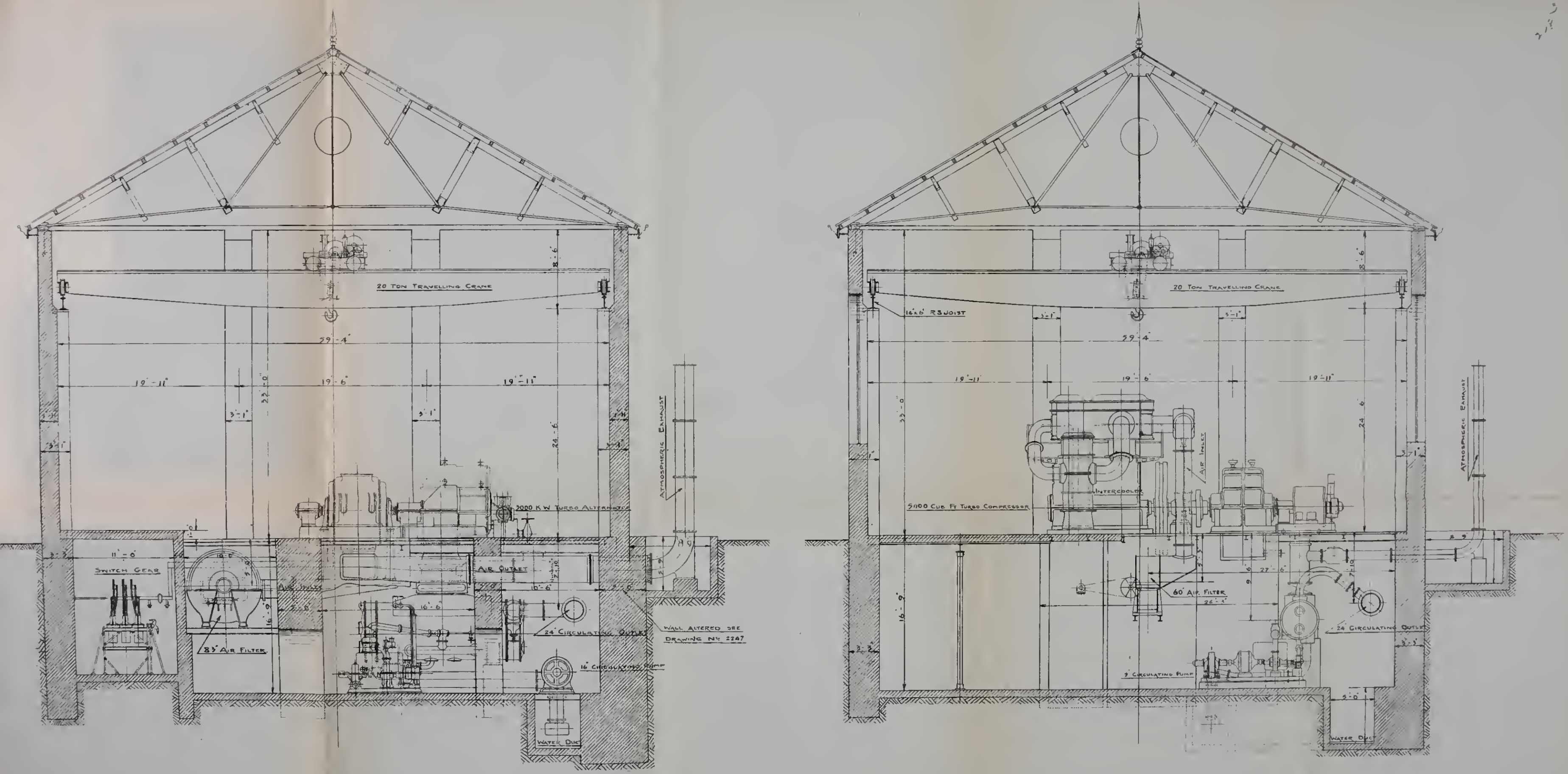
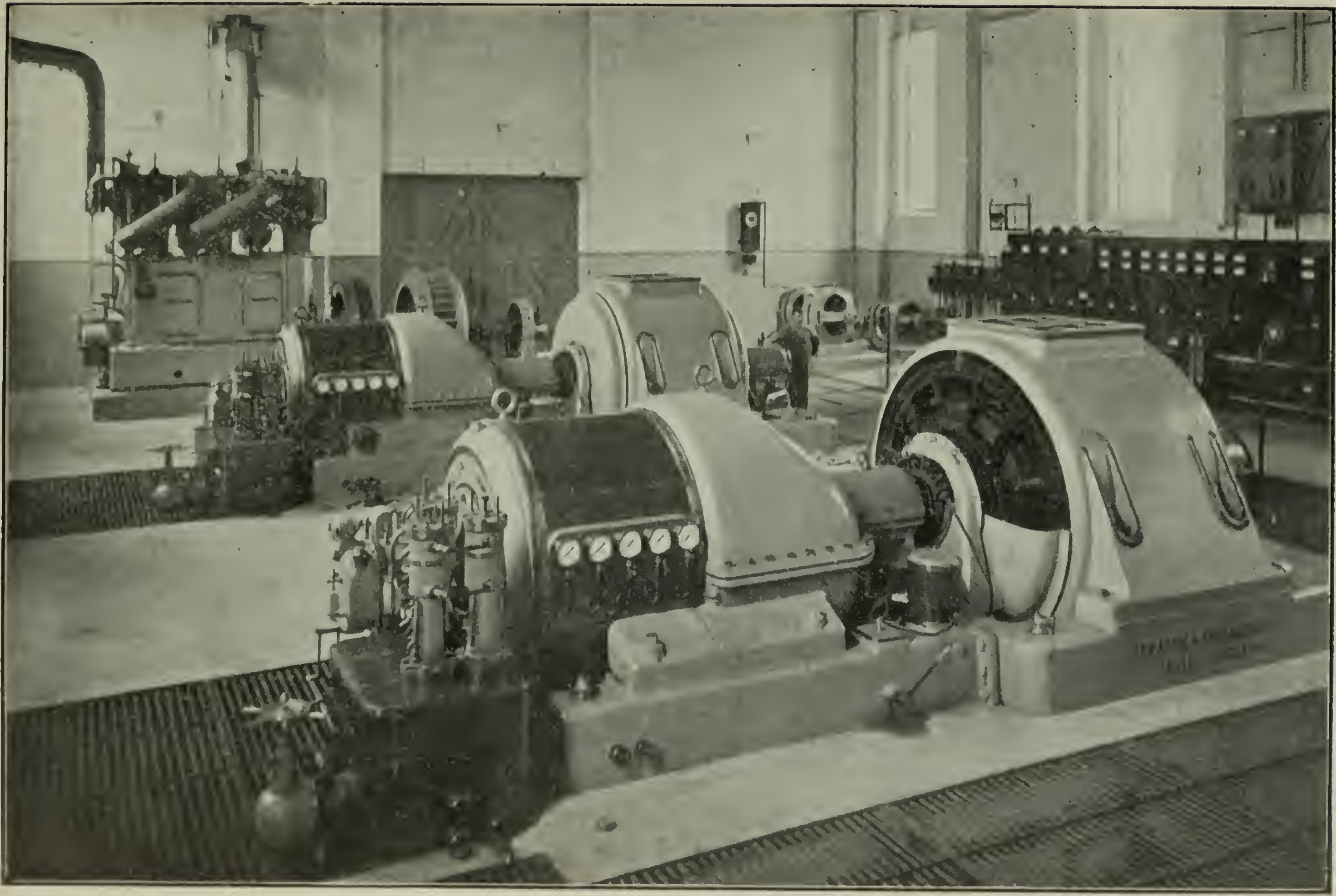
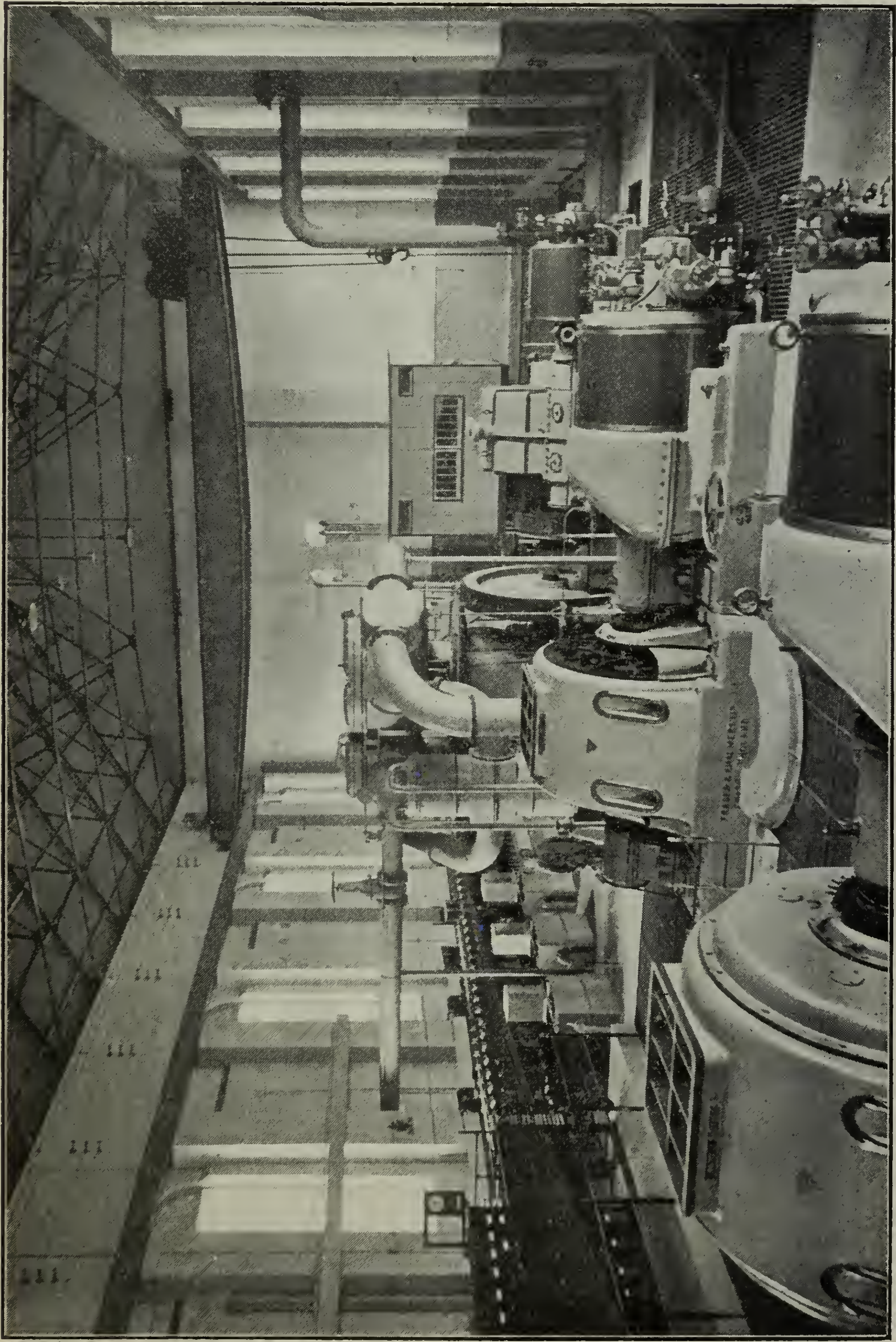
3000-KW. Alternators.



ARRANGEMENT OF NEW POWER PLANT.
Scale—¼ In. = 1 Ft.



3000-kw. Alternators.



General View of Power House.

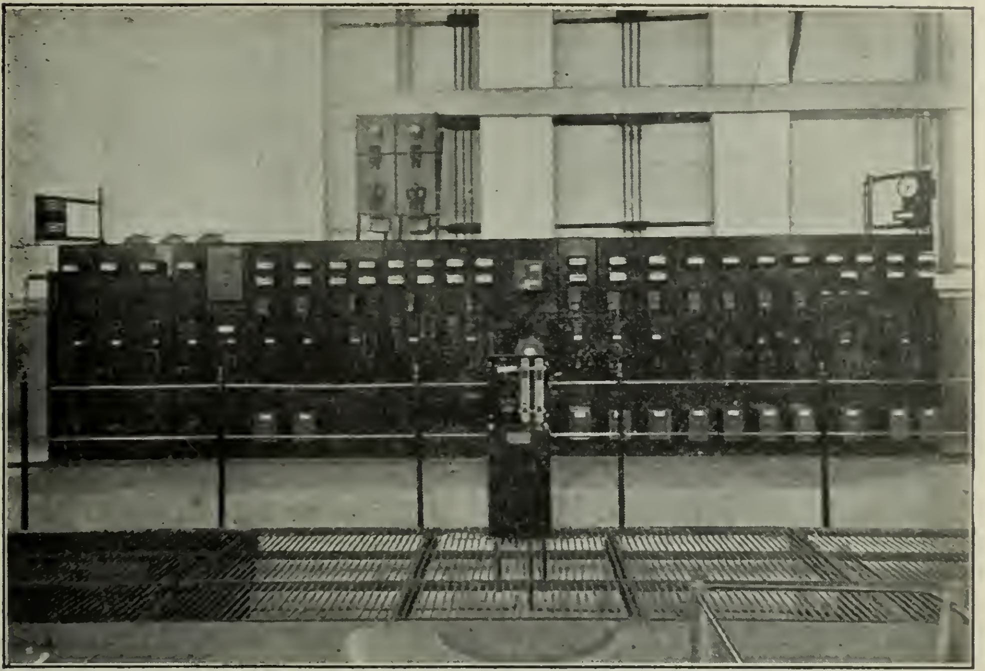


FIG. 1.
Control Board.

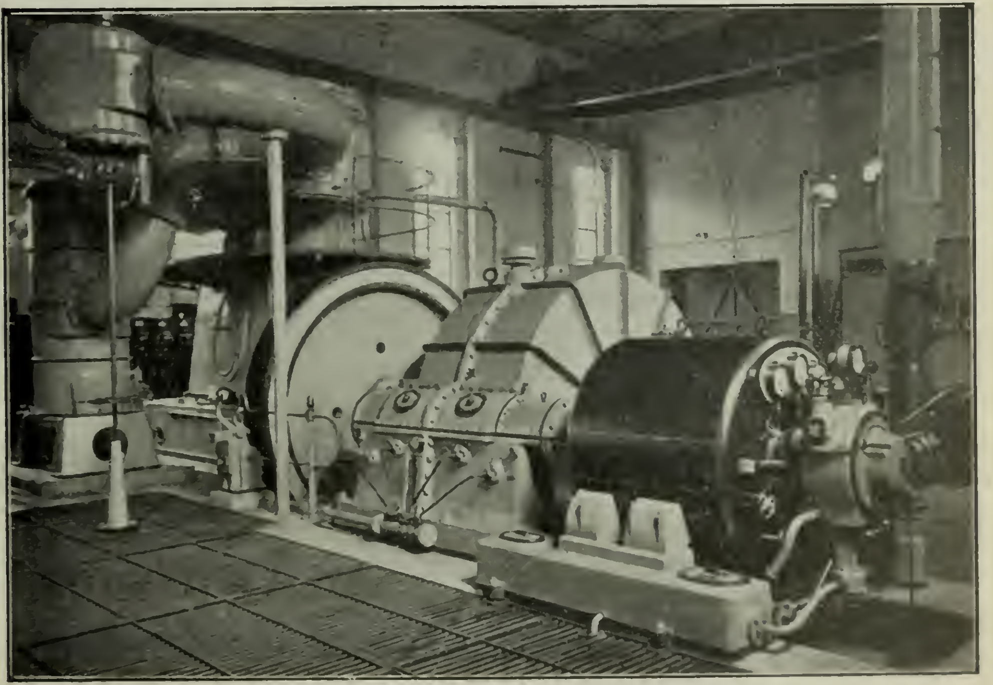
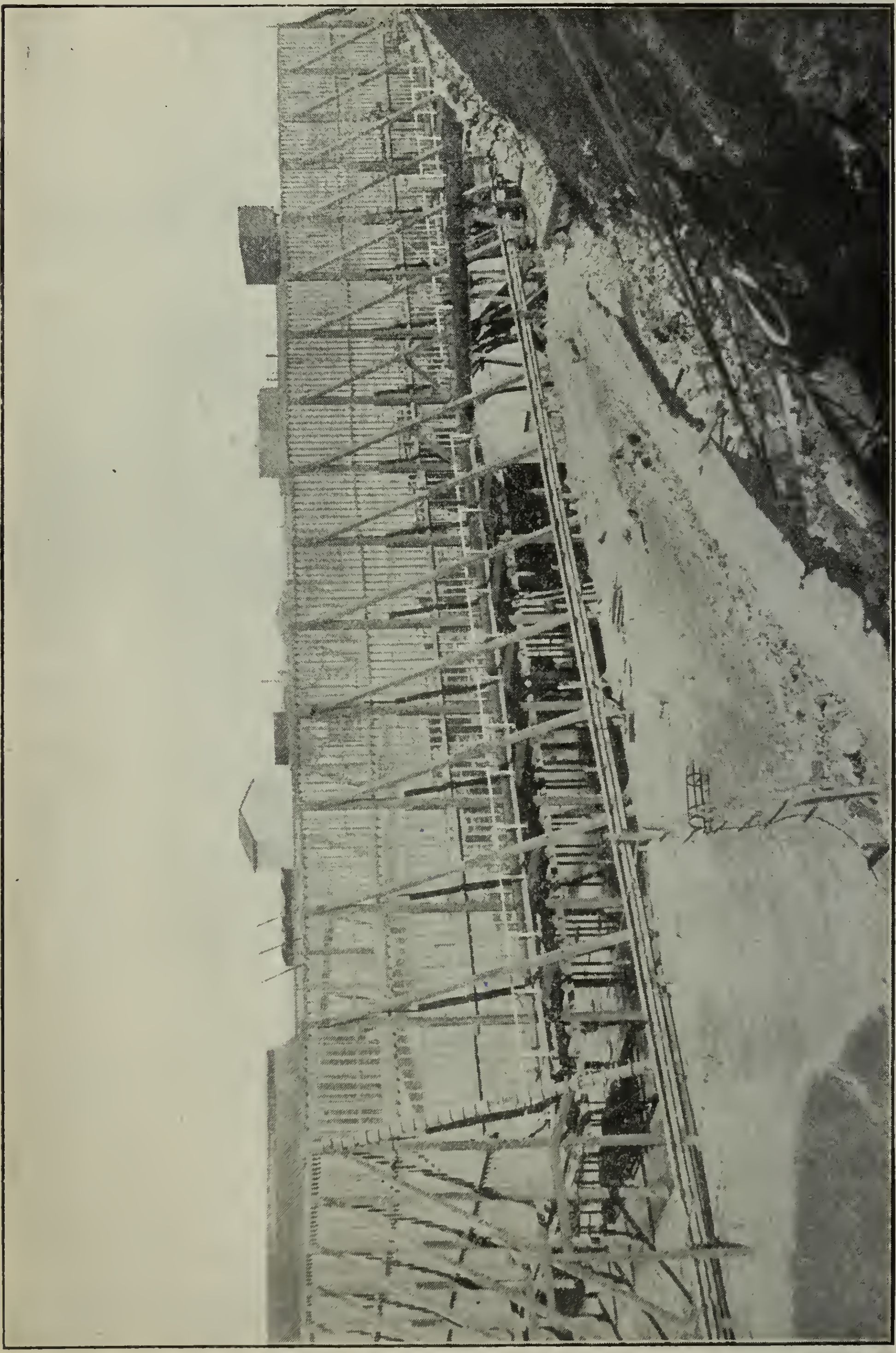


FIG. 2.
5000 cub. ft. Compressor.



Cooling Tower—Exterior.

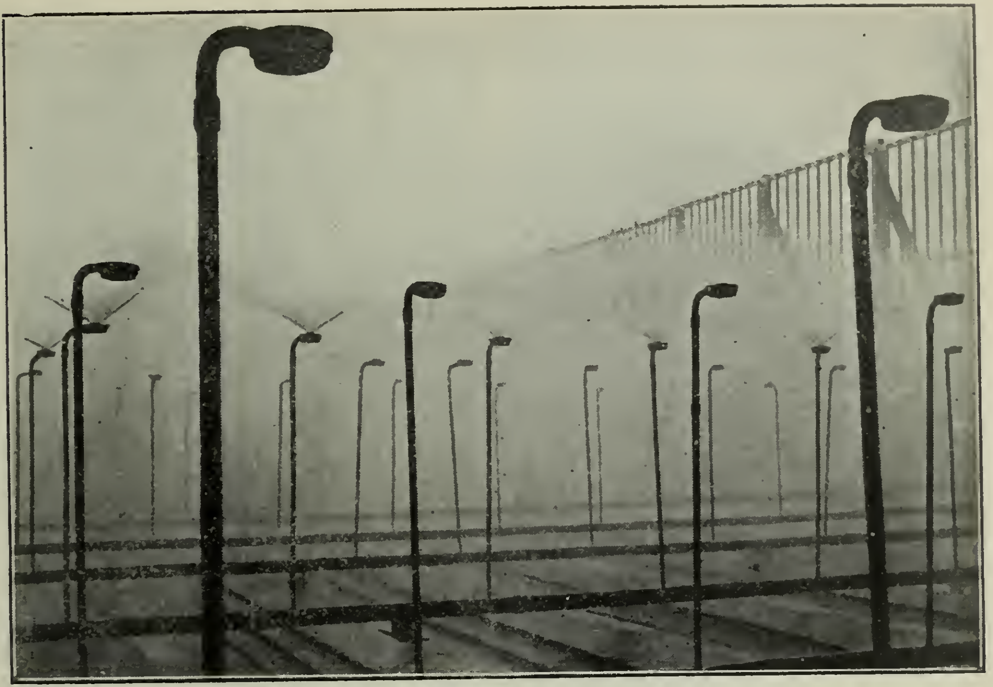


FIG. 1.
Cooling Tower—Interior.

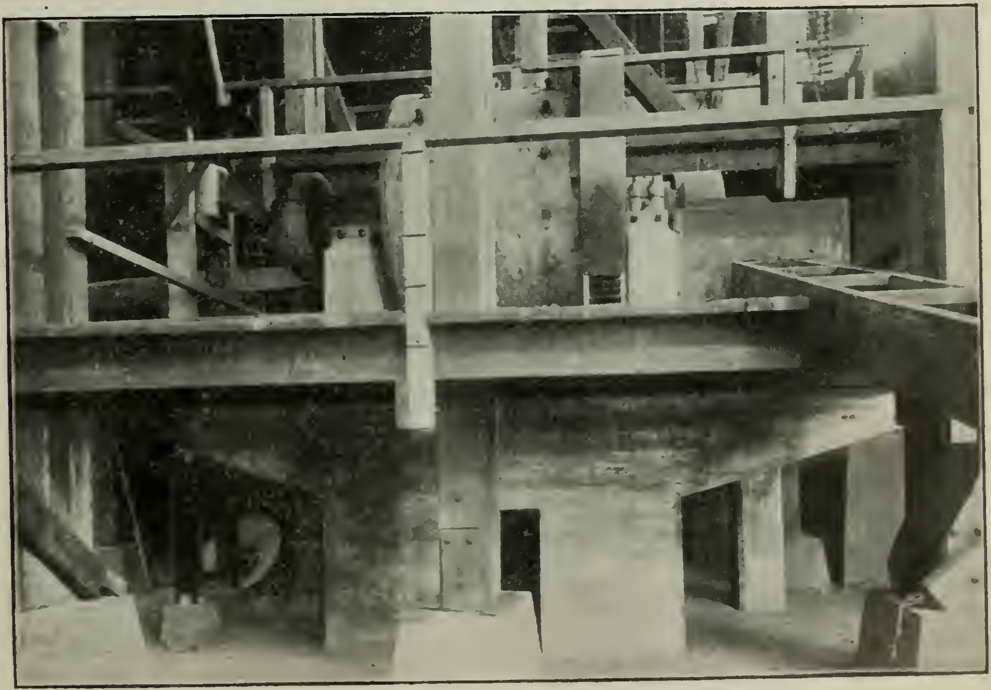
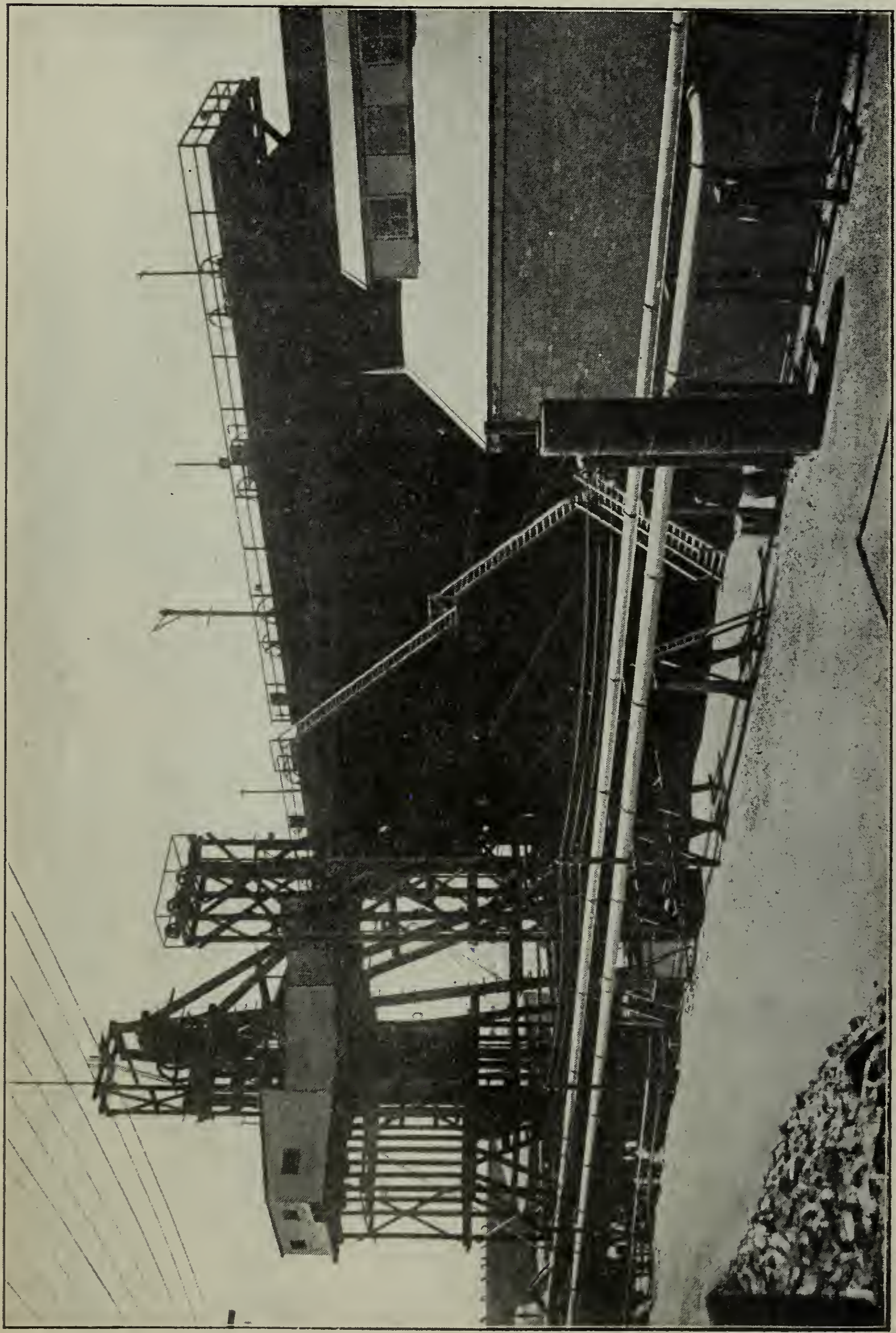
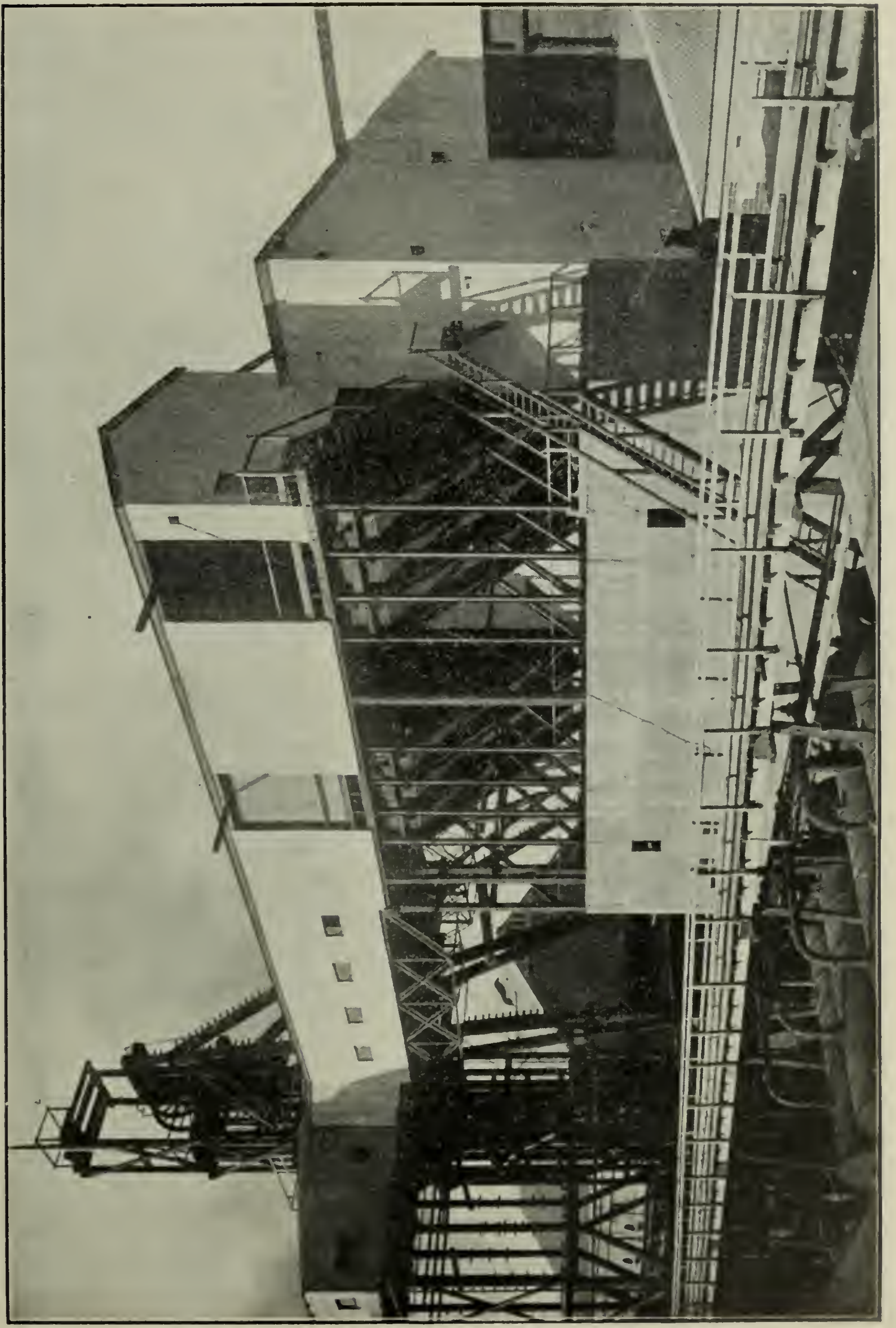


FIG. 2.
Marcy Mill Section.



Old Bin Structure burned down.



New Reinforced Concrete Structure.

MECHANICAL METHODS OF ALLAYING DUST.

BY P. H. WARREN.

(*Discussion continued 22nd and 23rd August*, 1921.)

MR. F. DANVERS POWER said he was under the disadvantage of never having had an opportunity of seeing the Clifton dust-allaying apparatus at work. He could therefore only form opinions from the experience of others, and it was always unsatisfactory to look at things through other people's glasses, which might happen to be coloured. Still, the opinions of those who had experience must be given due respect, for in coming to conclusions they had secured much evidence, often of a negative nature, which was not published, for, if placed on record, it would go far to scare others from studying the subject on account of the mass of matter to be gone through, and on that account the amount of good such researches might do would be limited. The subject under discussion had to be approached from so many different directions that they really required the services of specialists on such subjects as chemistry, physics, mechanics, pathology, and even psychology. It was not, however, within the scope of any one of these to form general conclusions, but rather for the mining engineer, whose varied experience placed him in a better position to judge. It was generally conceded that the injury to the lungs was brought about by minute (less than 5 microns in diameter) particles and certain minerals with sharp edges, that which mostly concerned the miner being quartz. The result was pneumoconiosis in one form or another ; in the case of the quartz miner it was silicosis. The injury to the lungs made the victim liable to lung complaints, such as pneumonia and phthisis. Miners suffering from the latter were liable to spread the disease about to those who were ripe to contract it more readily in underground workings than at the surface, where there was a better circulation of air. Men who had contracted phthisis should not be allowed to work underground, for their own sakes, as well as for the sakes of their companions. Any mining where blasting was necessary must produce dust unless the rock was saturated with water. They could not prevent the dust; the best they could do was to control it. Some dusts appeared to do little or no harm to the miner. If coarse, it fell quickly to the ground; if finer it might be caught, as Nature intended it should be, if men breathed through their noses, but unfortunately most miners were mouth breathers. The very finest dust found its way into the lungs, from which certain dusts were rapidly removed by short-lived cells, with which they become entangled. The sharp, jagged particles of quartz worked their way between the cells, causing inflammation, which in turn produced fibrous tissue, and that ultimately enclosed the particles, retaining them in the lung. It would seem that if the harmful dust were diluted with dust which was rapidly removed the latter helped to get rid of the former before it could do any harm. Coal miners and drovers, who must, in following their vocations, breathe in large quantities of dust, were not affected in the same way as quartz miners. He was not aware that, so far as Broken Hill was concerned, it had been conclusively proved the miners had contracted silicosis there. A man may contract phthisis without necessarily having silicosis first; or his past history might show that he had worked in quartz mines elsewhere before going to Broken Hill. They had heard a good deal about counts, and the comparison of results with the konimeter and gravimetric methods of determining the amount of dust present. It seemed to him that neither was right as at present used, especially the gravimetric method, which did not allow for the size of the particle unless a fair length of time was allowed for settling. What was wanted was not the number of particles of dust, but the number of particles of injurious dust. If there were a large number of harmless particles, they may be an advantage. These counts were only relative, and all the particles did not remain behind in the lungs when once they reached there, neither did all the air in the workings necessarily pass through the lungs of the men. The method of sampling also seemed unsatisfactory unless a very large number of samples were taken over a lengthy period, and, after all, the sample was a very small proportion of the whole. One had not the advantage of sight to assist him in determining whether the sample was a fair one as when dealing with ore. They must look upon it as sampling a fluid. The friction of the air against the walls of the workings would retard its progress and help to settle any dust ; air-currents would tend to keep the particles in suspension ; exhaust air from drills would dilute the particles in a given volume. In fact, it seemed almost impossible to obtain anything but the crudest sample. The number and weight of the particles would also depend on how soon after the dust was made that the sample was taken, and whether it was secured near its source or some distance from it. Atomizers might wet particles and cause them to sink quicker than if they were dry ; but, so long as there was any fog, particles remained in suspension, and they were just as harmful wet as dry. Although the minute sharp particles of quartz might be the direct cause of injury to a miner's lung, there were also other things to be considered as affecting the health of the miners, such as excessive temperature and humidity. An overheated man reaching the cold air of the surface in winter or at night was very liable to catch cold, and if his clothes are saturated with perspiration because the underground air already had 100 per cent. moisture, he was still more likely to get chilled. At some mines in America and Europe, where the climate was inclement, there were covered gangways between the shaft and the change room. The miner's attitude of mind must also be taken into consideration. He was apt to think more of his present feelings than of more important health matters which would affect him in the future, and which were not so obvious to him. Also, he would often take unnecessary risks, and neglect to use or take care of appliances that had been provided for his welfare, either because he was indifferent or thought it was some fad of the " boss," or possibly thought the " boss " was trying to get at him. It was no use introducing a rule or appliance unless its use was enforced.

Mr. C. H. J. Clayton said the konimeter gave fair average samples. He asked, Was the atomizer any use ? Would the dust rise again later after the atomizer had been removed to some other place ? In a medical way they were in the dark. Ninety per cent. of the men examined by a special commission were judged to be suffering from silicosis. Of this number, 34, according to report, contracted the disease in Broken Hill. The remaining cases were contracted in sewers or mines in other States. Regarding the second stage of the ailment, 44 men were found to be suffering, and only 8 of them contracted the disease in Broken Hill. In the first stage most of the cases concerned workers of very advanced age.

Mr. Danvers Power: How could one distinguish between a Broken Hill and a South African case?

Mr. Clayton said they did not quite know whether it was possible for that to be done. Regarding lung diseases, he suggested that the shape of the quartz particles caused them to be retained in the lungs.

Mr. G. C. Klug said there was a marked distinction between a Broken Hill lung and a silicosis lung, as had been proved by radiograph photography. According to the report of the Commissioner, the damage done to the Broken Hill miner was nothing like that done to the quartz miner working in the Transvaal. By paying close attention to the allaying of dust, much progress had been made lately in South Africa.

Mr. J. M. Bridge said members of the Institute were greatly indebted to Mr. Warren for his paper, and to the members of the Broken Hill Branch who had contributed so largely to the discussion. The discussion had not been confined to the subject-matter of the paper, but had embraced allied subjects and the health of underground workers. Men of all occupations were prone to ascribe the adverse state of their health to their occupation, and preferred, as a remedy, the improvement of their own conditions by working less hours for more pay rather than the improvement of the working conditions by eliminating the causes of ill-health. Mining engineers took the opposite view, and aimed at so improving the underground conditions that they would be equal to those enjoyed by surface workers. Quartz dust in mine air had for years been recognized as being injurious to health, and in South Africa, where the results of the inhalation of this dust were most marked and extensive, commendable efforts have been made to cope with the evil. Up to the present the investigators at Broken Hill had wisely made use of the work done in South Africa, and had used the same preventive and recording apparatus. Members who had not investigated the determination of dust-particles present in underground air were apt to erroneously conclude that the air in their mine was free from dust. The dust that one could see was mainly over 5 microns, and innocuous; but air which appeared to the eye to be as clear and free from dust as on the surface might contain the injurious (under 5 micron) dust in injurious quantities. The value of the konimeter for determining the dust-particles in the air had been questioned, but, so long as its limitations were recognized, it was of undoubted value. One might just as well discard the barometer as a guide to weather conditions, because it did not infallibly indicate that rain would or would not fall, as throw aside the konimeter before some better apparatus was developed. The konimeter was a handy, easily-manipulated instrument, which was capable of expeditiously giving roughly quantitative comparisons of the dust in mine air, and, as such, was a valuable addition to the equipment of the mining engineer. One good result of the Broken Hill investigations had been the development of the Clifton apparatus, which, although it could not be successfully employed in all classes of work, had a distinct sphere of usefulness, especially when used with a popper. The results given by Mr. Warren proved that the dust from boring could be efficiently allayed by using axial water-feed drills, outside water-jets, or the Clifton apparatus, and, as those three methods differed widely in their application, each had probably a sphere in which it was superior to either of the others. The dust from shovelling could be eliminated by the use of the water-hose to wet down the rock pile. Mr. Warren's paper had caused a lively discussion on the suppression of dust from blasting. There appeared to be a general agreement, in which he (the speaker) concurred, that the water-blast was advantageous in development work, confined spaces, and dead-ends, but its value in large stopes had been strongly disputed. It was well to bear in mind that the large stopes of Broken Hill were the exception and not the rule, and that dust suppression applied to all mines and in the aggregate to small stopes. Air-currents, sufficient to quickly clear the workings of dust and noxious gases, were certainly desirable, but in large stopes the velocity of the current was decreased, eddy currents were formed, and considerable diffusion took place. The combination of these factors increased the difficulty of ventilating the large stopes, and consequently of effecting the removal of the dust by the ventilating current. Adequate ventilation was necessary for reasons other than dust removal, while the water-blast aimed solely at allaying the dust in the vicinity where it was produced, and preventing its circulation and diffusion throughout the workings in the air-current. The water-blast might be inefficient in allaying dust in some stopes ; it might unduly increase the humidity in others ; but there were places where it would effectively lay the dust without unduly increasing the humidity. It rested with the engineer to adopt the water-blast where it was suitable, and to avoid doing so where it was not suitable. Mine air without high temperature, humidity, and dust contents was what was required, and any attempt to lay down hard and fast methods of achieving the desired result was to be avoided, as it would block progress and adversely affect some section of the mining industry in which local conditions varied so widely.

Papers and Discussions.

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CONCENTRATING PRACTICE OF THE BROKEN HILL SOUTH LIMITED, BROKEN HILL, NEW SOUTH WALES, AUSTRALIA.

BY W. E. WAINWRIGHT AND T. A. READ.

PART I.

THE CONCENTRATING PLANT.

GENERAL.

THE Broken Hill South Ltd. is one of ten companies operating on the Broken Hill lode (See Fig. 1). It has two leases—Blocks 7 and 8—of a total length of 2250 ft. on strike of lode.

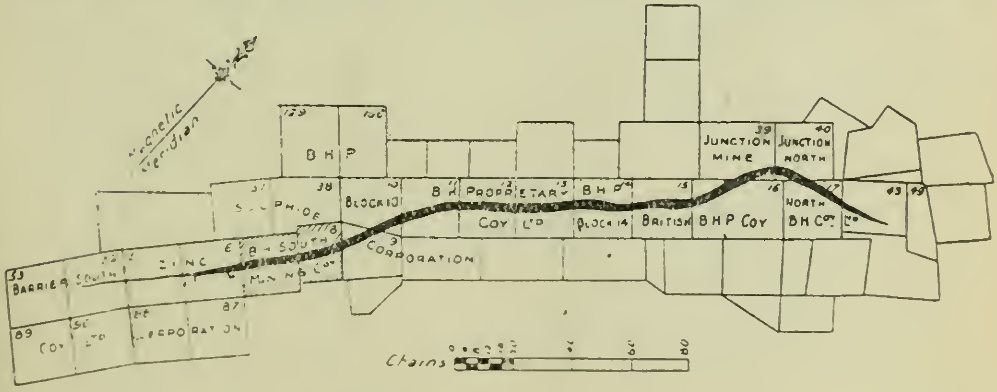

FIG. 1.

PLAN OF BROKEN HILL LEASES SHOWING COURSE OF LODE.

From the surface to 425-ft. level the ore was found principally in the form of carbonates and high-grade friable sulphides. Below the 425-ft. level the ore is found in the form of compact sulphides.

The ore-bodies found in the South mine may be broadly divided into two classes—

(1) Silicious. (2) Calcitic.

The following are typical analyses of these ore-bodies :—

—	Silicious.	Calcitic.
	%	%
Insoluble (Silica, &c.)	37.71	30.12
Lead (Pb)	15.50	13.40
Copper (Cu)	.10	.20
Arsenic (As)	.18	.43
Antimony (Sb)	.03	.06
Iron (Fe)	4.90	3.03
Alumina (Al_2O_3)	2.40	1.25
Manganese (Mn)	2.47	1.70
Lime (CaO)	4.00	15.70
Zinc (Zn)	17.00	12.60
Sulphur (S)	13.80	9.70
Carbon dioxide (CO_2)	1.30	11.60
Fluorine (F)	.24	.078
	99.63	99.868
Silver, oz. per ton	11.7	3.2

The insoluble portion in the above analyses has the following composition :—

—	%	%
Silica (SiO_2)	67.6	56.0
Ferrous oxide (FeO)	4.6	6.6
Alumina (Al_2O_3)	4.6	3.5
Manganous oxide (MnO)	19.5	17.7
Lime (CaO)	3.0	13.3
Magnesia (MgO)	.9	2.5
	100.2	99.6

The principal minerals occurring in the ore-bodies are :—

Galena. Blende. Pyrite.
Pyrrhotite. Arsenopyrite. Chalcopyrite.
Calcite. Fluorspar. Garnets.
Rhodonite. Quartz. Feldspar.

It will be noted that the calcitic ore-body is considerably lower in zinc, silica, and iron, and much higher in lime than the silicious portion. The mines operating on the northern (*i.e.*, North Broken Hill Co.) and southern end of the line of lode (Broken Hill South and Zinc Corporation) have that class of ore in which the calcite content is high compared with the ore in those mines working on the central portions of the line of lode.

This difference in the mineral contents, which also means a difference in the physical character of the ore, accounts for the slight variation in the system of concentration practised in the different plants on the field. This remark applies more particularly when the by-products from the lead concentrating mills are to be treated subsequently by the flotation process. The calcitic ores require a much larger proportion of sulphuric acid to recover the blende.

HISTORICAL.

The South mine started developmental operations in the year 1885, mining oxidized ores, the tonnage extracted being sold to neighbouring companies who were operating lead smelters.

In 1888 a few experiments were made in a small way with a Cornish hand-jigger. In 1891 three 80-ton blast-furnaces were erected on the mine to smelt the oxidized ores. At the end of two years the supply of oxidized ore of sufficiently high grade to make it payable was exhausted, and the smelters closed down. Developmental work was continued at the mine, and in 1894 the first lead-concentrating plant was erected to treat the friable sulphides opened up in the upper levels.

This plant consisted of a Blake-Marsden rock-breaker, with 12-in. x 7-in. jaws, one pair of Cornish rolls 27 in. diam. with 15-in. face, followed by trommels. The undersize from the trommels passed to a small hydraulic classifier, while the trommel oversize was sent to a 14-ft. raff wheel, and returned to the rolls for re-crushing. The trommel undersize, which was fed to the classifier, was separated into two products. The coarse material from the classifier was fed to Hancock jigs, while the slime overflow was sent to storage dam.

The average feed to this mill assayed

36 % Pb, 5 oz. Ag, 18.5 % Zn,

and the concentrate produced by the jig assayed

71 % Pb, 9.2 oz. Ag, 6.7 % Zn.

Early in 1895 two additional Hancock jigs were put into position, making a total of four. A 20-ft. diam. Cornish buddle was installed for experimental work on the slime overflow from the classifier; later in the year three more buddles were put into commission treating this slime, the slime being classified into coarse and fine, and treated separately on the buddles.

In 1896 a large Cornish crusher with 15-in. x 9-in. jaws was added to the plant, and in 1897 an additional six buddles, three slime tanks, and accessory plant for conveying the slime from the tanks to the buddling plant were put into commission. In 1899 the crushing plant was re-arranged, and connected to the ore bins; the smaller (12-in. x 7-in.) jaw-crusher was replaced by one having 15-in. x 9-in. jaws. In 1900 five Wilfley tables for treating the coarser portion of the slime tailing replaced the buddles, and an experimental May Bros.' plunger jig was installed for re-jigging old tailing. In 1901 two No. 5 Gates gyratory breakers replaced the jaw-crushers, and also a third set of 33-in. x 15-in. rolls was added. In the same year a re-grinding plant, consisting of eight Heberle disc grinders, was installed, and, to take care of the larger quantity of fine material, four fine May plunger jigs and seven Wilfley tables were added, making 12 tables in all; in the slime section six Luhrig vanners replaced the Cornish buddles, treating the fine slime.

With these additions the concentrating plant was able to treat normally 3000 tons of crude ore per week, but was occasionally treating up to 4000 tons per week. In 1903 a six-compartment May's Duplex plunger jig was installed for comparative test purposes on the jigging of crude ore. During the period these milling operations were in progress the developmental work at the mine revealed very extensive ore-bodies, and by December 30, 1904, the mine ore reserves were 1,300,000 tons.

With the larger ore reserves, the management decided that an increased output from the mine was possible, but, as the concentrating mill had been built on the top of the lode, and, owing to the various alterations and additions, had become too congested to permit of further extension, it was decided to investigate the proposition of building a new concentrating mill. In the meantime experiments were continued to determine the most suitable machinery for incorporation in the new plant.

At this old plant, in 1905, two Krupp ball mills for fine grinding replaced the Heberle mills. These Krupp ball mills, after a long series of tests, were superseded in 1906 by 11 Forwood Down grinding pans, 5 ft. in diam. Grinding pans 7 ft. 6 in. diam. and a 5-ft. Middleton Cobbe grinding pan were also tested out, but they had nothing to recommend them over the 5-ft. diam. Forwood Down type. Late in 1906 a Krupp tube mill 14 ft. x 4 ft. 7⅛ in. diam. was erected, and tested against the grinding pans. It was found that, from a concentrating point of view, the two types of grinding machines were nearly equal, but the cost of crushing by the tube mill was lower than by the grinding pan. For full details of this test see paper No. 170, published in the *Transactions of the Australasian Institute of Mining Engineers*, vol. xiii.—" Fine Grinding," by W. E. Wainwright and W. J. M'Bride.

In 1907 the fine jigs were replaced by Wilfley tables, making a total of 24. These tables were of modified design, to suit local conditions. After careful experimenting, all slime separators, spitzkastens, and fine jigs were discarded. The three coarse jigs (two Hancock and one May Bros.) were fed with an unclassified feed. The jig tailing and middling, after being ground in 12 Forwood Down grinding pans and the tube mill, were fed without classification to the 24 Wilfley tables. The slimy overflow from the Wilfley tables, after being thickened, was fed unclassified to 12 Luhrig vanners, better results being obtained than from the former imperfect classification.

Raff Wheels and Bucket Elevator.—In this plant the raff wheels were driven from an extension of the roll shaft. This arrangement gave considerable trouble with the roll shaft bearings on account of the spills cutting out the bearings. Before erecting the new mill, one of the raff wheels in the old mill was replaced by a belt and bucket elevator. and it was found to give much better results; in addition, it allowed of a better design of trommel. For these two reasons the belt and bucket elevator was chosen for returning the raff to the rolls in the new mill.

Experiments had advanced sufficiently by the end of 1905 to enable plans to be prepared for the erection of a new gravity concentrating mill to treat 6000 tons of crude ore per week.

The erection of this new plant was begun in 1905, and completed and placed in operation on the 20th May, 1908.

At the time when the plant was designed, the "flotation process" was in its infancy, and no such developments as the "preferential flotation of galena" from mixed minerals was known. Hence the general design of the crushing and re-grinding section of the plant was directed towards crushing fine enough to liberate the galena from blende and gangue, and to produce the minimum of slime, which at that time could not be concentrated, and was run out into slime dams from thickening pits.

Ore Reserves of Mine.—At the end of 1906 the estimated ore reserves were 2,000,000 tons. Developmental work has since been steadily carried out, and the ore reserves are now estimated at 3,500,000 tons.

Ore Mined and Treated.—From 1885 to 1st May, 1919, the crude ore raised and treated equalled 4,858,617 tons, assaying 16.2 % Pb, 6.7 oz. Ag, 13.7 % Zn.

The concentrating mills, which were started in 1894, have produced, to date, 890,337 tons of lead concentrate, assaying 67.2 % Pb, 21.0 oz. Ag, 7.5 % Zn. Prior to 1894, the ores were treated by the smelters.

2,535,000 has been distributed in dividends.

NEW CONCENTRATING MILL IN 1908.

Figs. 2 and 3 show the plan and elevation of the mill. In general lay-out it was divided into four sections, each capable of treating 250 tons of crude ore per day of 24 hours. The ore, as it reached the shaft brace, was tipped into one of four bins; from these bins it gravitated either to one of three No. 5 Gates gyratory breakers or a 30-in. x 18-in. Hadfield jaw-crusher. Single-stage crushing was practised, and the run of mine ore was reduced to 2-in. gauge. The crusher discharged direct into bins, situated immediately below; the ore was then drawn from these bins as required, and elevated to the mill crude-ore bins by a system of crossed conveyor belts, 18 in. wide. Situated at the throw-over station of the crossed conveyor belts was the sampling plant, which will be described separately.

The crushed crude ore was distributed over the mill crude-ore bins, four in number, by an auto-tripper, which could be run over any mill bin. The roll-crushing, jigging, and fine-grinding portion of the

CENTRATING PRACTICE—BROKEN HILL SOUTH LIMITED. FIG 2.

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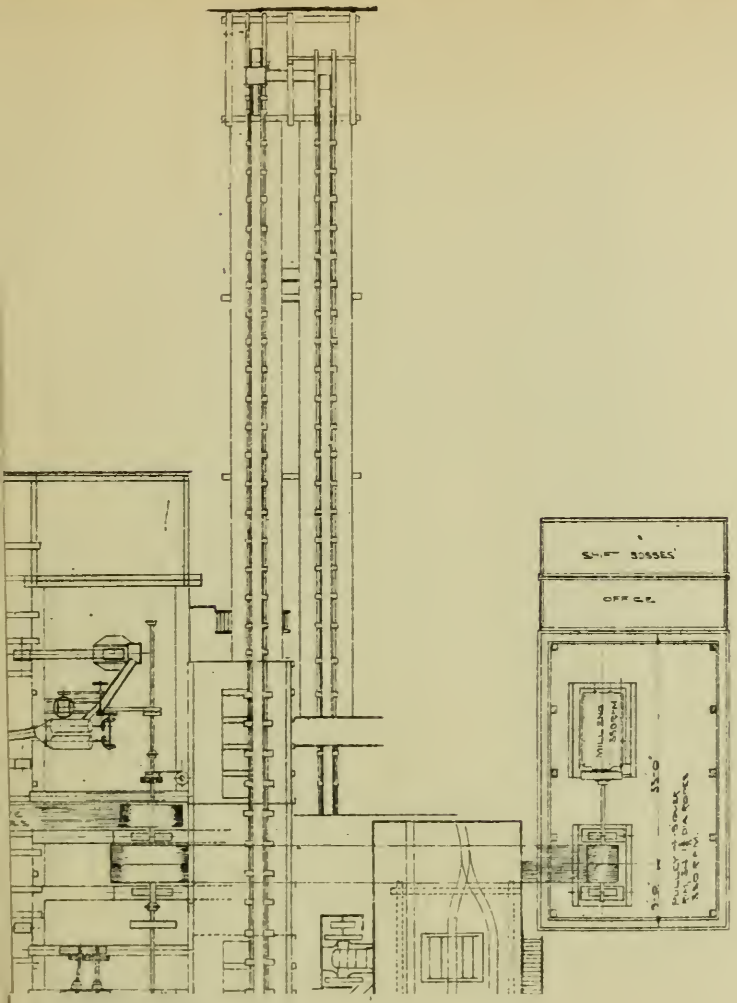
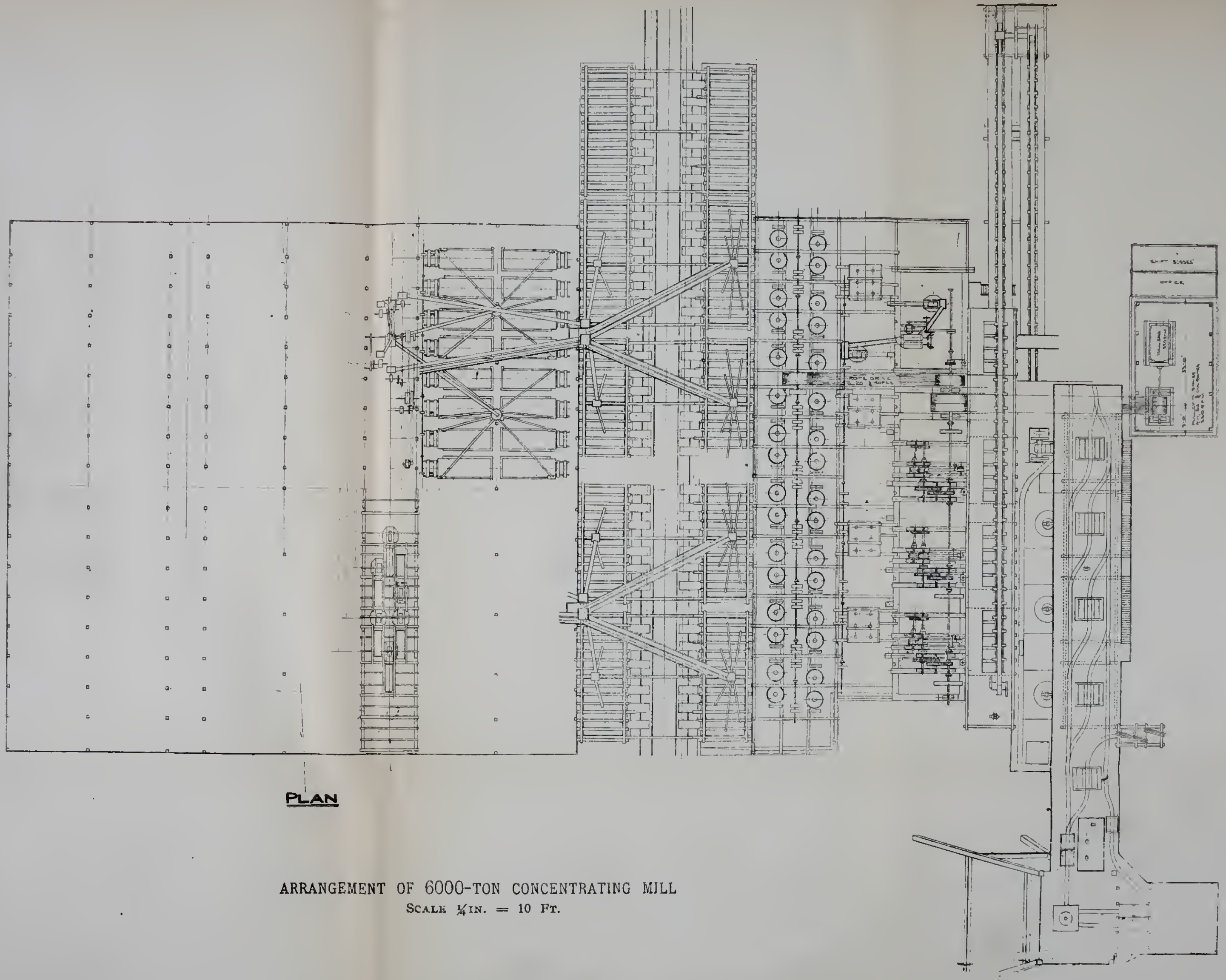
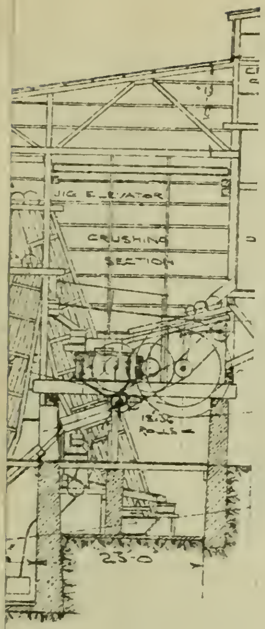


FIG 2.



ARRANGEMENT OF 6000-TON CONCENTRATING MILL
SCALE ¼ IN. = 10 FT.



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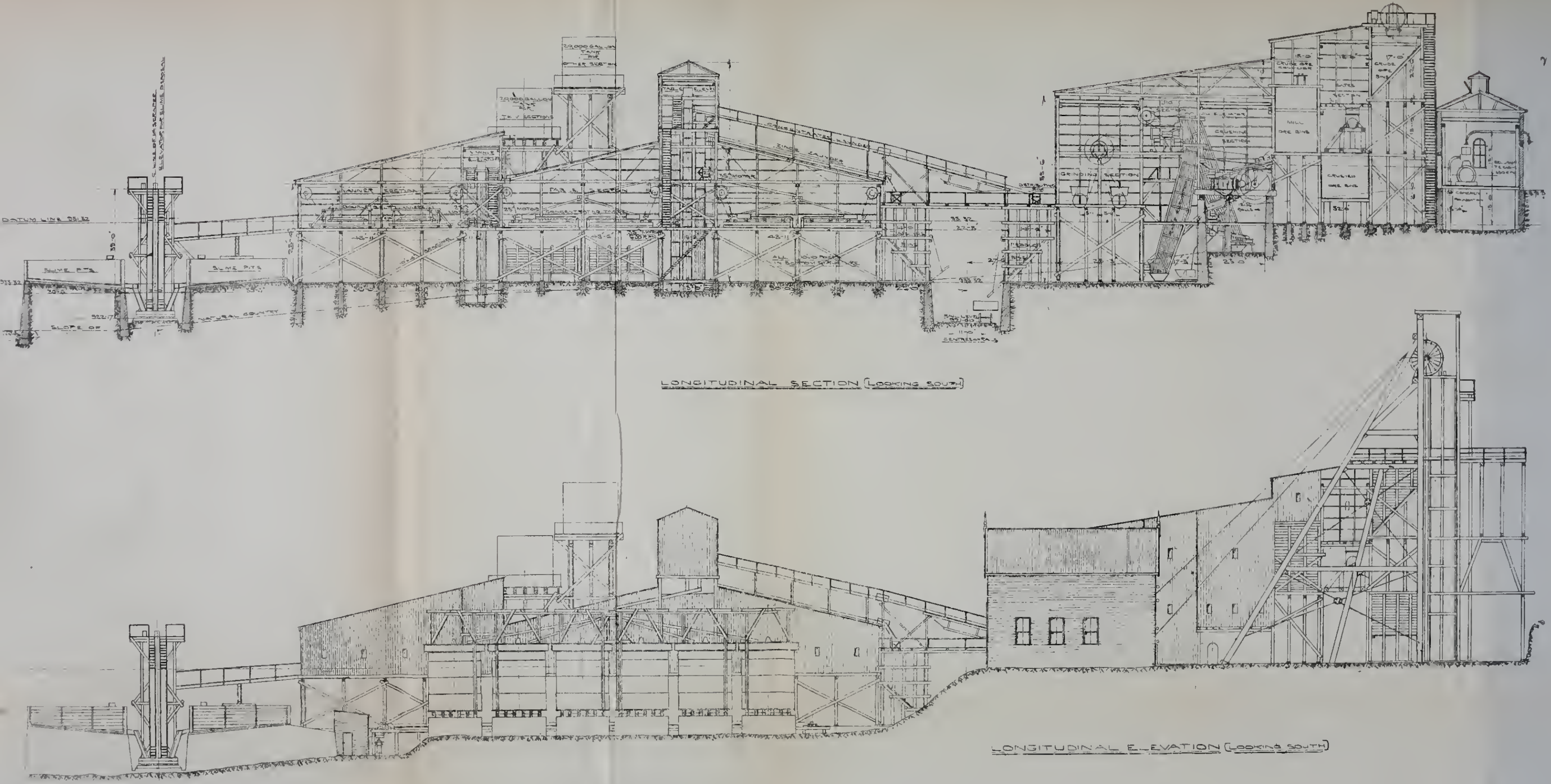

LONGITUDINAL SECTION (LOOKING SOUTH)

LONGITUDINAL ELEVATION (LOOKING SOUTH)

ARRANGEMENT OF 6000-TON CONCENTRATING MILL
SCALE ⅛ IN. = 10 FT.

plant was divided into four sections, which could be run as required, while in the tabling portion of the plant the tables were divided into four sections, with one elevator system supplying each double section.

GENERAL DESCRIPTION OF ORE TREATMENT PER SECTION IN 1908.

The ore was drawn from the bin by a roller feeder and delivered on to a shaker. A portion of the shaker bottom was made of 4 mm. slotted screen; water was added to the shaker, which washed some of the undersize through the screen, to later on join the trommel undersize. The oversize passed to 36-in. x 18-in. rolls, and the product delivered to a pair of revolving trommels, fitted with 3 mm. round-hole screens.

The oversize or raffs were returned to the rolls by an elevator, whilst the undersize, joined by the shaker undersize, was elevated and delivered over a sampling machine, and then to a duplex three-compartment May Bros. jig.

Three products were made by the jig—

- Lead concentrate, delivered to storage bins.
- Lead middling, returned to the jig.
- Lead tail, which gravitated to a set of eight 5-ft. diam. grinding pans.

The whole of the grinding pan discharge was elevated and distributed over 14 Wilfley tables per section, which made five products, as follows:—

- Lead concentrate, delivered to storage bin.
- Lead-zinc middling, which was re-treated on two additional tables.
- Zinc tailing, sent out to storage bins, and subsequently dumped or re-treatment, and later sold to the De Bavay Co. for treatment.
- Quartz tailing, which was used for underground filling.
- Slime tailing, which flowed to V-shaped thickeners, and were subsequently treated on six double-belt Luhrig vanners per section, where a further small quantity of lead concentrate was made.

All of the slime was collected in pits, thickened, and elevated to a slime dam.

The separation of products made by this mill during the first twelve months of its operations was as follows :—

TABLE I.

—	Tonnage.	% Prop.	Assay.			Proportion.		
			% Pb.	Oz Ag.	% Zn.	% Pb.	% Ag.	% Zn.
Lead concentrate ..	38,960	15.6	73.4	18.8	4.7	74.0	53.0	6.1
Zinc tail ..	70,189	28.1	4.0	3.4	18.7	7.2	17.3	43.5
Quartz tail ..	107,935	43.2	2.7	2.1	10.4	7.5	16.1	37.2
Slime tail ..	32,722	13.1	13.3	5.8	12.2	11.3	13.6	13.2
Crude ore ..	249,806	100.0	15.5	5.5	12.1	100.0	100.0	100.0

At this period of the company's operations the whole of the lead concentrate was sold to German firms, who had a strong preference for high-grade lead concentrate. To enable this to be produced, it became necessary to eliminate as much of the slime as possible from the feed to the jig.

Small hydraulic classifiers were first tried, with only partial success ; subsequently these were replaced by a pair of King revolving screens, fitted with 30-mesh cloth. Only the oversize from the screen was delivered to the jig, while the undersize passed on to the table section.

In 1909 the South Co. entered into a contract with the De Bavay Co., on a joint-profit basis, for the treatment of the South Co.'s zinc tail. It therefore became necessary that as much as possible of the zinc content of the crude ore should be delivered to the De Bavay Co. To enable this to be done, finer grinding was necessary.

Experiments carried out on the jig tail with one section of the re-grinding plant, grinding in closed circuit, with 16-mesh revolving screens, gave a product comparatively free from the coarse blende particles, which were not recoverable by flotation. The whole plant was subsequently altered to this system, and completed by the end of 1909.

The milling plant ran under the above conditions for eighteen months, with the following result :—

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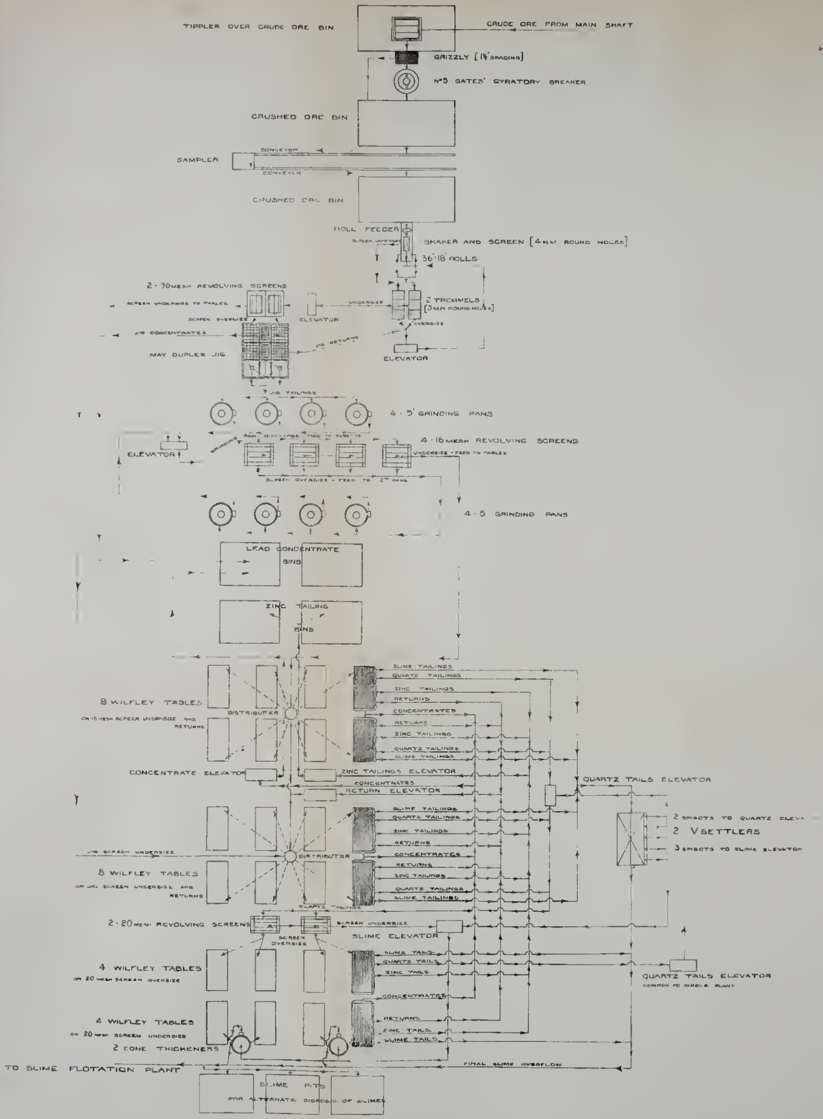
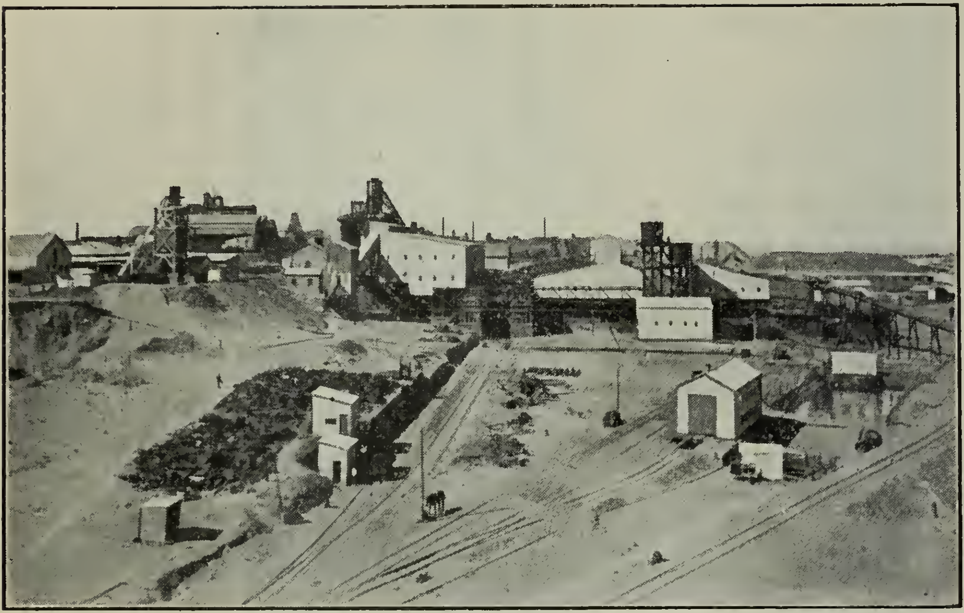
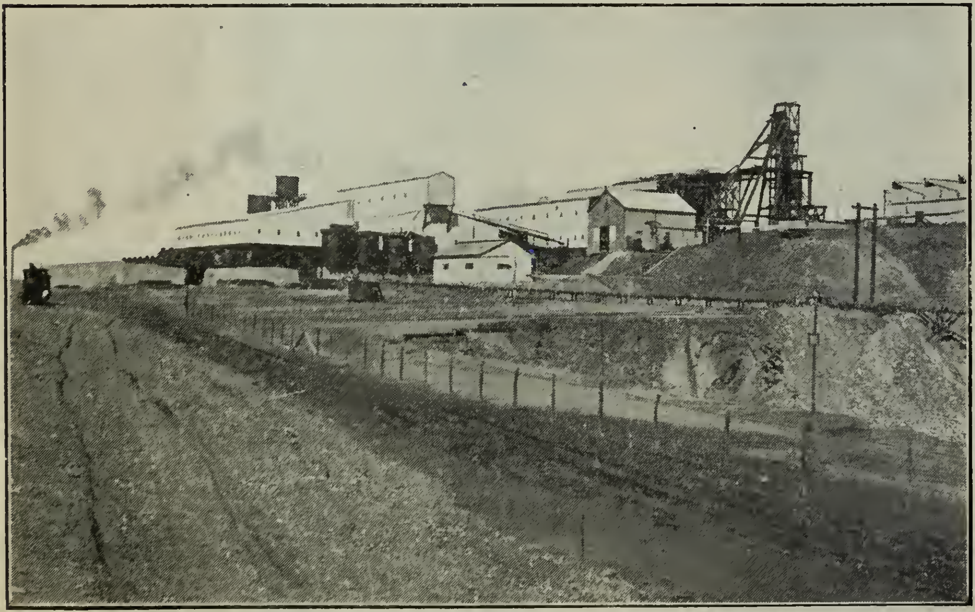


FLOW SHEET.

South Mine looking South West—June, 1921.



Concentrating Mill looking North East, 1908.



Concentrating Mill looking South West, 1908.

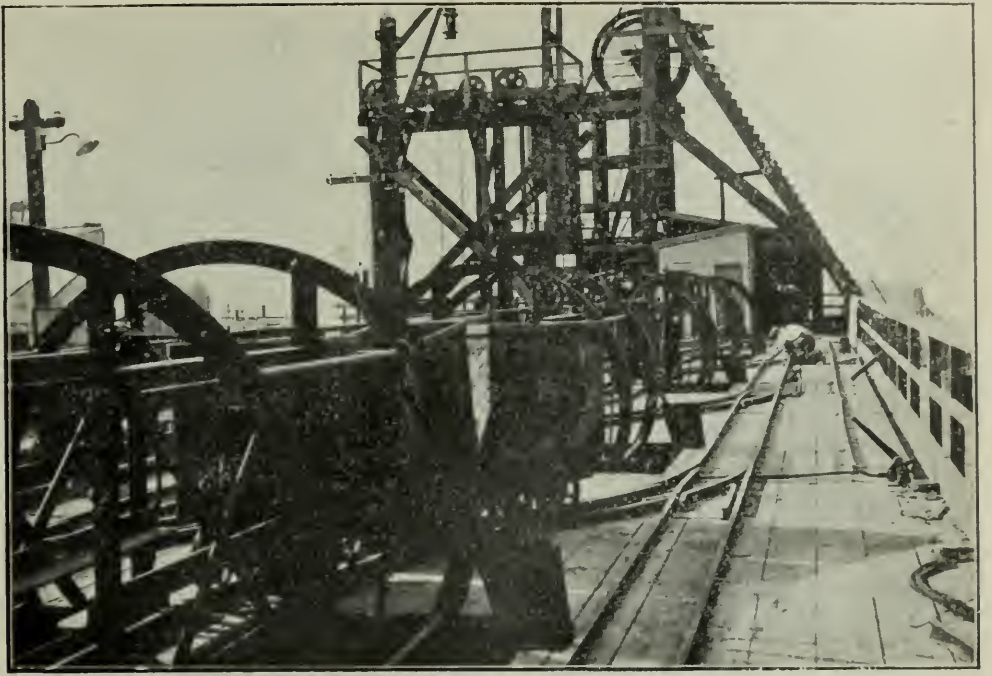


FIG. 1.
Tumblers over Mill Crude Ore Bins.

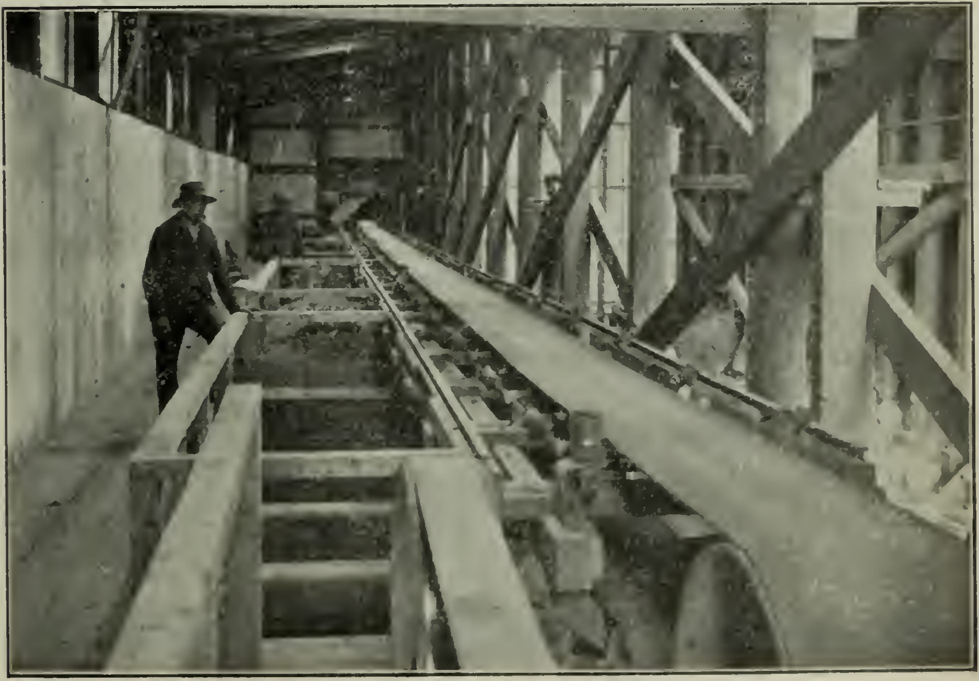
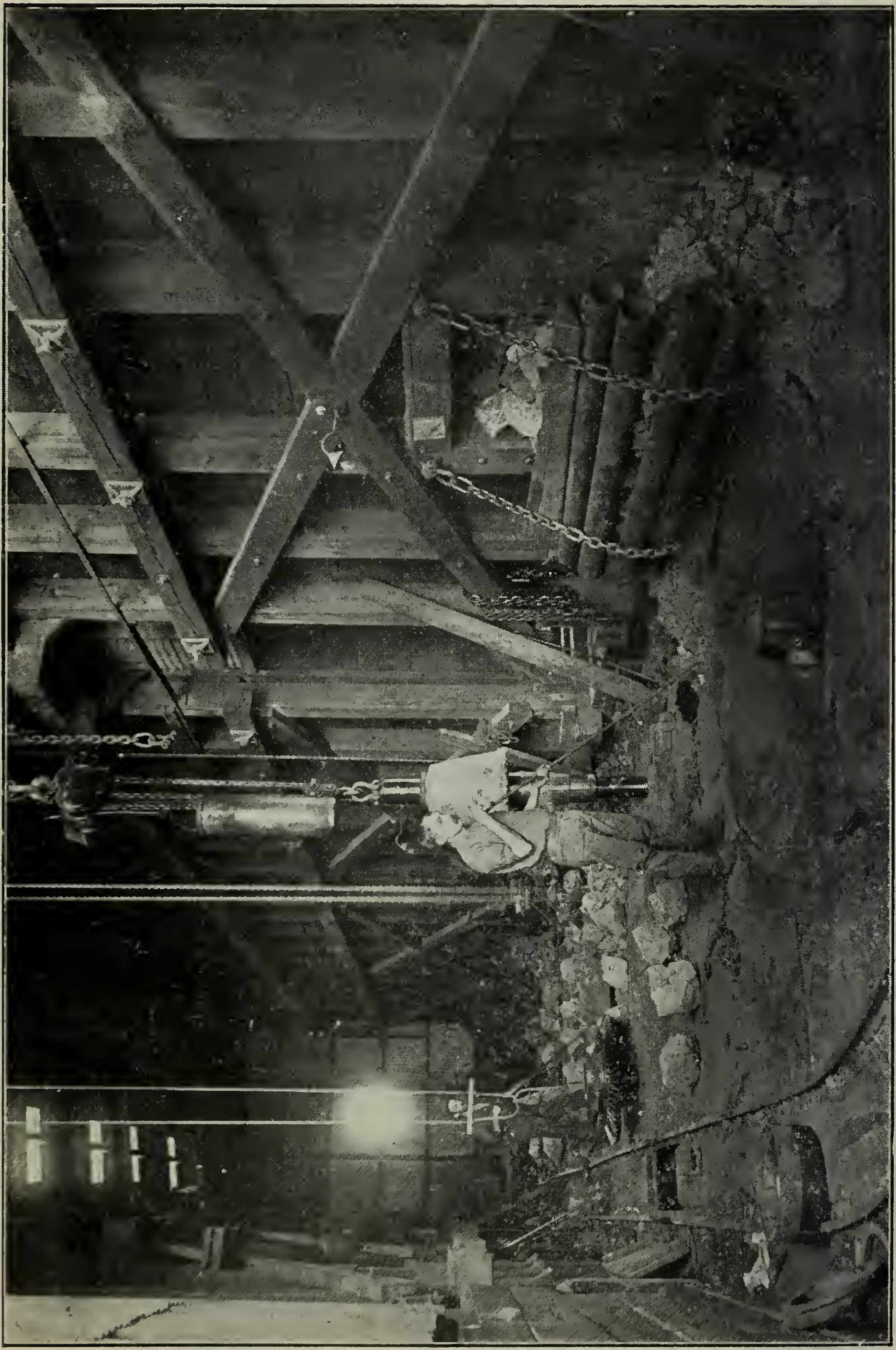


FIG. 2.
Conveyor Belt over Mill Crushed Ore Bins.



Gates' Breaker Feed Floor.

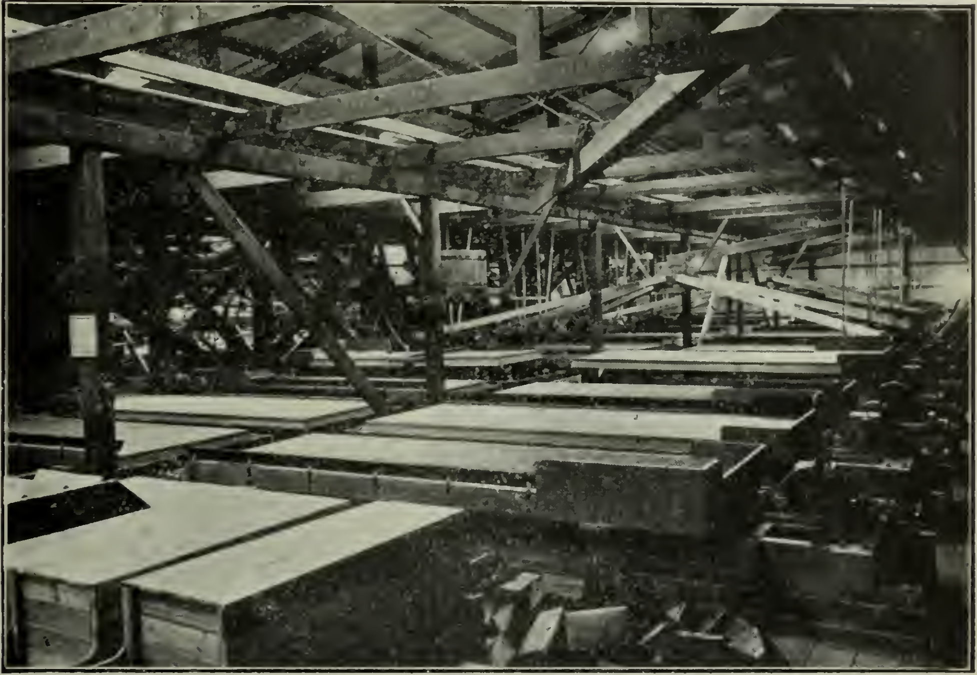


FIG. 1.
Wilfley Table Section.

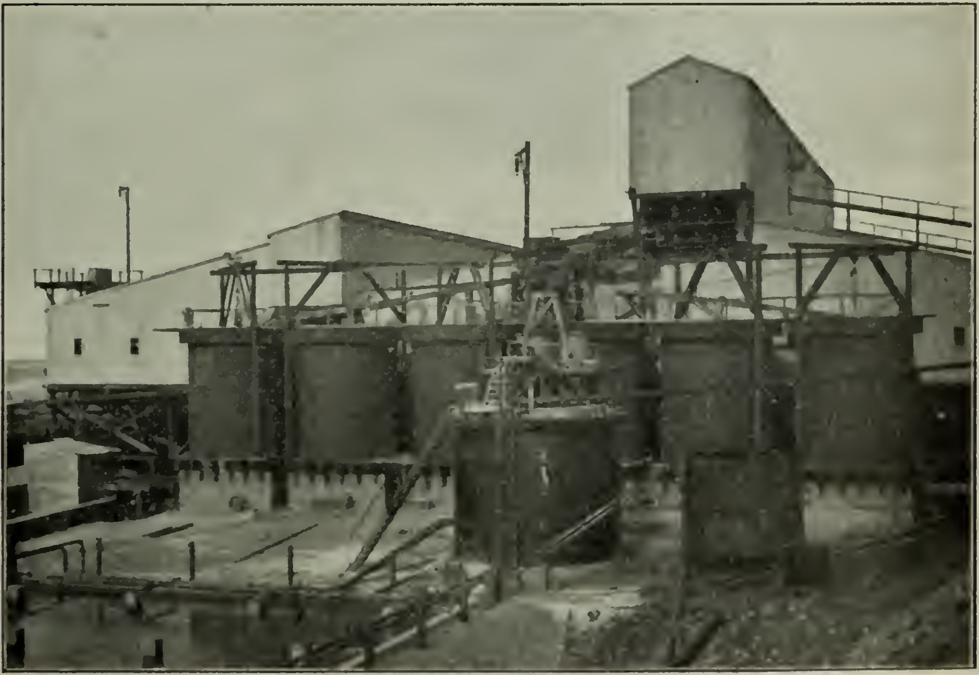
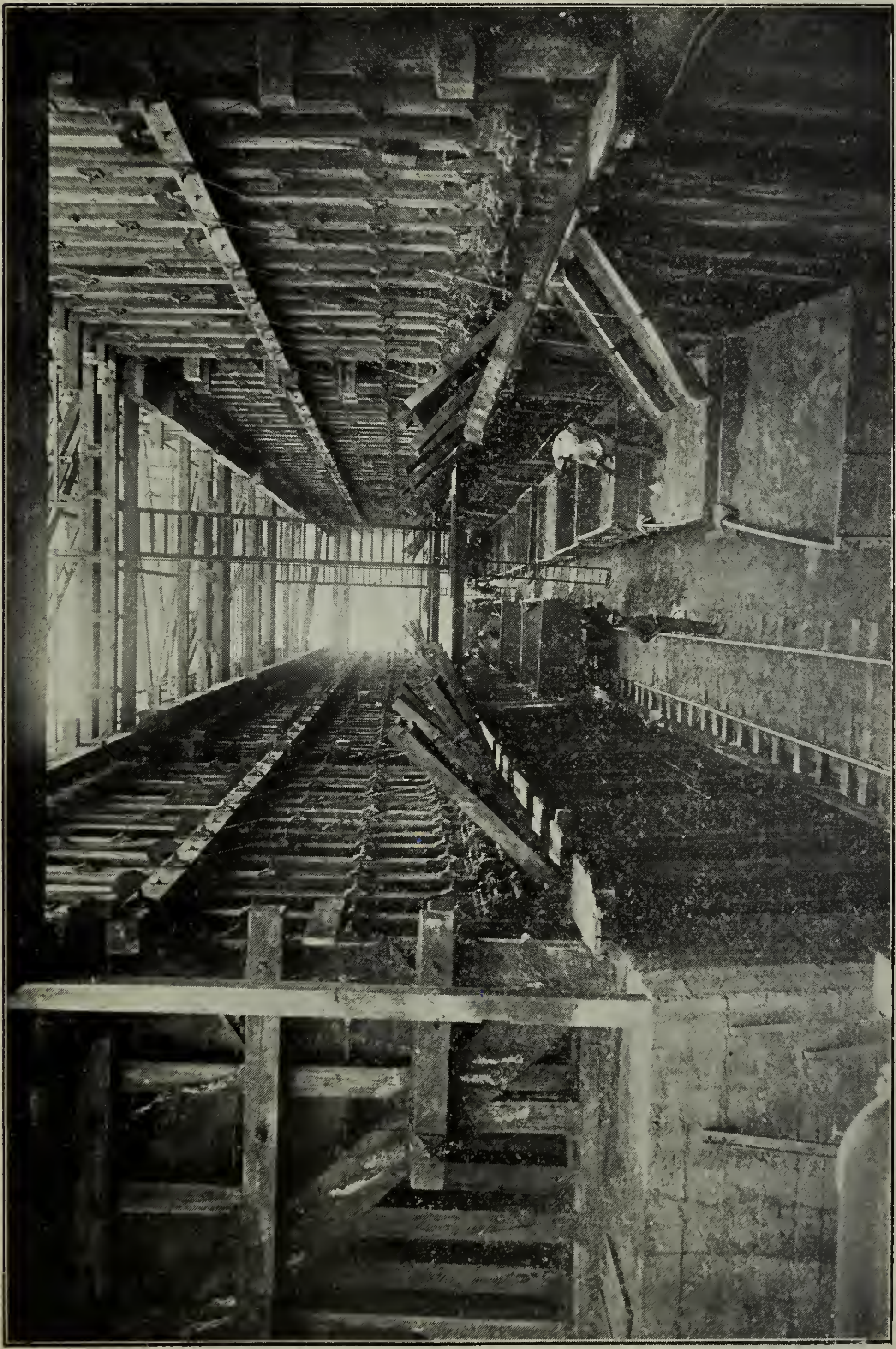


FIG. 2.
Quartz Tails Vats.



Product Bins—Zinc Tails and Concentrates.

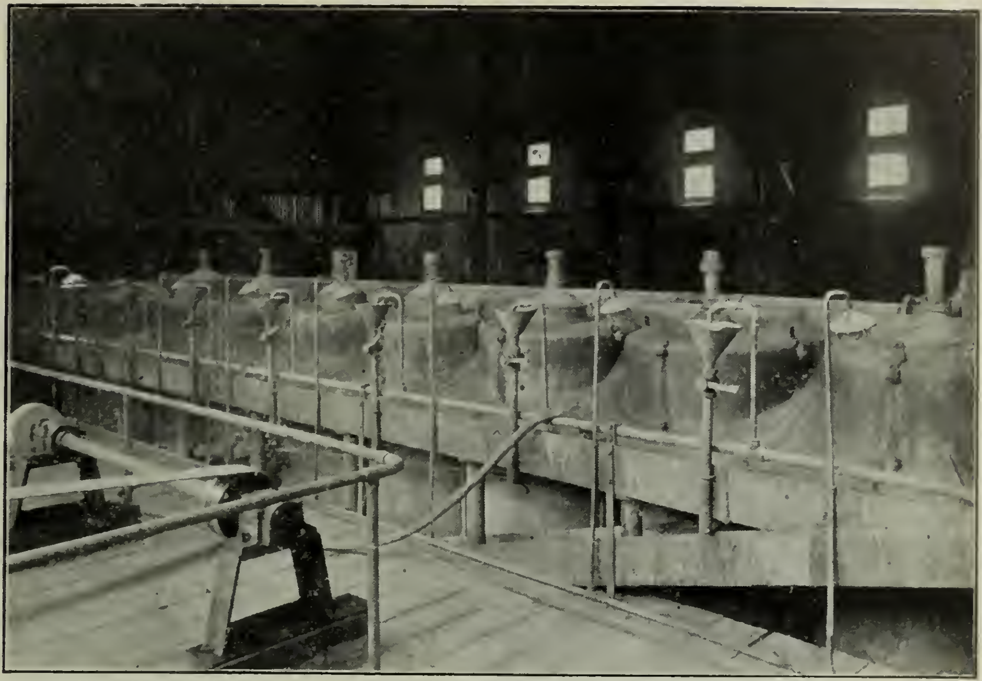


FIG. 1.
Cunningham Flotation Cells.

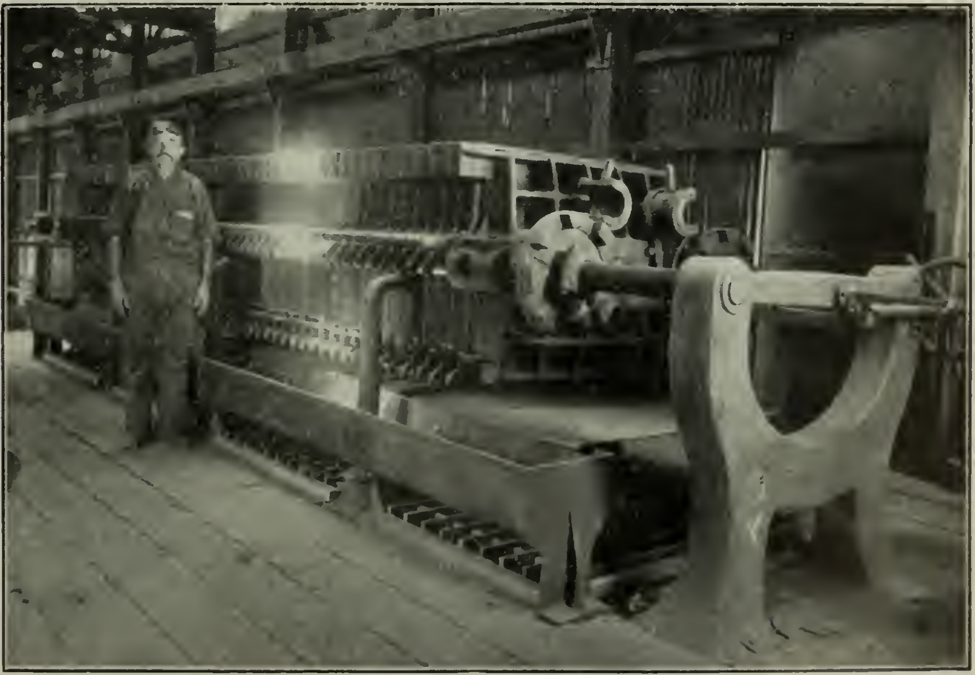
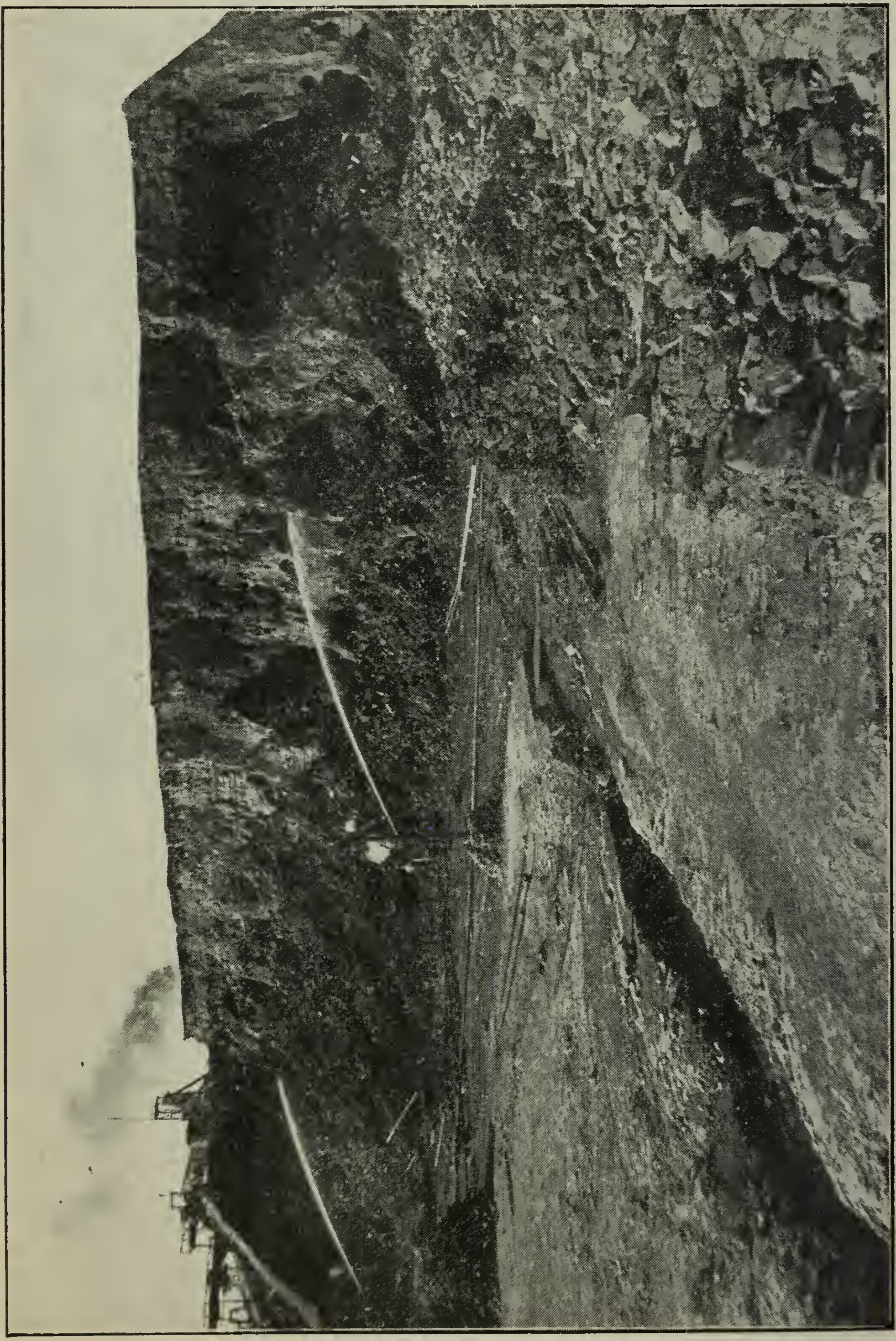


FIG. 2.
Leaf Filter Press for Slime Lead Concentrate.



Hydraulicing Dump Slime for Flotation Plant. Old Oxidized Lumps in foreground

TABLE II.

—	Tonnage.	% Prop.	Assay.			Proportion.		
			% Pb.	Oz Ag.	% Zn.	% Pb.	% Ag.	% Zn.
Lead concentrate ..	73,428	15.3	71.7	21.0	5.3	73.7	53.3	6.5
Zinc tail ..	212,438	44.3	4.1	3.6	18.2	12.4	26.4	63.5
Quartz tail ..	130,715	27.3	2.3	1.8	8.3	4.2	8.2	18.0
Slime ..	62,786	13.1	11.0	5.6	11.6	9.7	12.1	12.0
Crude ore ..	479,367	100.0	14.9	6.1	12.7	100.0	100.0	100.0

In the above segregation of products it will be noticed that 18 % of the total zinc was sent out in the quartz tailing, and dumped underground.

Experiments were conducted with this material to try and recover the larger proportion of the zinc by mechanical methods.

To add the quartz tailing to the zinc tailing would have the effect of lowering the grade too much, and, in addition, cause a very much higher acid consumption when treated by flotation, on account of its high calcite content.

Tests on a commercial scale proved that by screening the quartz tailing on a revolving screen with 20-mesh cloth, and tabling the undersize and oversize on separate tables, the greater portion of the zinc could be recovered in a sufficiently high grade product suitable for zinc flotation treatment at the De Bavay works.

As the Luhrig vanners were recovering very little lead concentrate, and tests showed that by combining the thickened slime from the V thickeners with the undersize from the 20-mesh screens, and tabling the mixed slime and sand, the same recovery could be made, the Luhrig vanners were taken out and replaced by tables ; these alterations were completed in 1911.

Only minor alterations have been made to this plant since that date. In 1915 a slime flotation plant was erected, and put into operation in 1916.

The following is a detailed description of these plants as at present equipped.

GRAVITY CONCENTRATING MILL, 1918.

Fig. 4 shows the flow-sheet of this plant as it was arranged at the time of the disastrous fire in the crushing section in July, 1919.

The accompanying photographs (Plates I. and II.) are views of the completed plant.

Conveyance of Ore from Brace to Bins.—The main shaft is situated on the footwall side of the lode, and it is arranged that all full trucks enter the cages from the western side of the shaft, and all empties leave the cages on the eastern side at every plat underground. On the surface, at the brace, all empties enter the cages from the western side, and all full trucks leave the cages on the eastern side, so that the passage of trucks through the cages is always in the one direction —*i.e.*, from west to east.

Trucks.—These are of the box type, with roller bearings. They tare, when empty, 6 cwt., and hold approximately 20 cwt. of crude ore.

Weighing.—The weighing on the brace is done by hand, in presence of a check weighman, on a 2-ton Pooley weighbridge. The weight of ore in each truck is credited to the party whose ticket is attached thereto. A spare bridge is kept in case of an emergency.

Trucking Lines on the Brace.—The lines are fitted with small railway-type switches to direct the trucks into their respective tipplers. Each return switch has spring points to automatically direct the empties to the return lines on coming out of the tippler.

Ore Inspection.—This takes place between the weighbridge and the tippler. A special employé is engaged on each shift to have any suspected trucks tipped into a small bin between the weighbridge and the first crude-ore bin. From this bin the suspected ore is pulled on to a tray. The mullock is thrown down a chute into a lower storage bin, and then trucked to a dump, while the ore is loaded into a truck, weighed, and then trucked around to the crushers.

Tipplers.—These are of the rotary, side-tipping type. The principle is utilized of having the centre of gravity above the rolling centre to give the motion. The truck can only run into the tippler, and not right through it. A lever with hardwood brake-block is used to help bring the tippler quickly to rest, and a hook catch prevents the tippler from turning over whilst being loaded. There are four of these tipplers, one over each crude-ore bin.

Crude-Ore Storage Bins.—These are four in number, with a total holding capacity of 800 tons. The bins are constructed of oregon, lined with steel plate, and protected on the bottom by grid bars, and have sloped bottoms. A grizzley is placed in each bin just at the door opening, forming part of the bottom of the bin. The ore passes over the grizzley and gravitates into the crushing machines.

Feed to Breakers.—The feed is as above described. Two men are attending these machines per shift of 8 hours.

Ore Breakers.—These consist of three Gates gyratory breakers and one 30-in. x 18-in. No. 5 type D Hadfield jaw-crusher, reducing the ore to 2-in. gauge. The Gates breakers run 60 % and the Hadfields 5 % of the total mill time. The Hadfield is mostly used to crush the rocks which are too large for the Gates. All wearing parts of the breakers have been sectionalized, to cheapen cost of renewals. The mantles are made in two pieces, and the concaves are bedded in zinc. The company's general experience with the Gates breaker is that the manganese steel mantles will crack rather than wear out when they are run on with zinc and subsequently burnt off. The later gunlock mantle is giving better results.

The No. 5 Gates are run at 390 r.p.m., and require 30 h.p. each. The Hadfield runs at 250 r.p.m., is driven by a 75 h.p. motor, and consumes 50 h.p.

Crushed Ore Bins.—These bins, four in number, are situated one under each breaker; they are constructed of oregon, have flat bottoms, and are lined with steel plate. They have a total capacity of 670 tons. These bins receive the crushed ore from the breakers, and the fines from the grizzlies.

Conveyor System.—The crushed crude ore is transferred from the crushed-ore bins to the mill-ore bins by a crossed conveyor. Each conveyor has 210 ft. centres, the belt is 18 in. wide, and the greater portion of the belt is operating at an angle of 18°, and the whole system elevates the ore 38½ ft.

Conveyance of Crude Ore.—From a rectangular opening in the bottom of each of the above bins, the aperture of which is governed by a sliding door, the ore is drawn by a feeder into a small chute, mounted on a carriage running on rails, so that the chute can be moved from one bin to another. The bottom of the chute is inclined in the direction of belt travel; two rubber-shod side-extensions help to centre the ore on the conveyor belts, and prevent it from rebounding from the belt.

The conveyor belt runs horizontally until clear of the bins, when it takes an upward curve, and runs at an angle of 18° until it delivers the crude ore at the sampling plant.

The sampling plant takes a $\frac{1}{200}$ cut out, and the balance of the ore-stream passes through a chute on to the return conveyor belt.

This return conveyor runs from the sampling plant to the mill storage bins at an angle of 18°, and then horizontally for the lengths of the bins. An auto-tripper serves to distribute the ore as necessary into one of the four roll-feed bins.

Both conveyor belts run on rollers with side idlers, and troughed throughout, except the horizontal portion of the top or second belt. The rollers and idlers are lubricated with grease by means of auto-compression grease cups. The following are the particulars of the conveyor belts :—

—	Length of centre.	Width of belt.	Speed in feet per minute.	H.P.	Tons per hour.
	ft.	in.			
Bottom belt ..	210	18	330	15	50
Top belt	210	18	400	15	

Magnet.—A magnet is situated on the incline of the bottom belt to remove as much tramp iron as possible.

Roll Feed Bins.—These are four in number, one to each section, constructed of oregon. They have a total capacity of 1100 tons.

Total Crude Ore Storage, 2570 tons.

Crude-Ore Sampling.—At this mine the crude ore milled is sampled at the sampling plant prior to entering the crushed crude-ore bins. This procedure was adopted after testing out the sampling mill against—

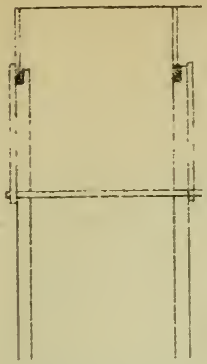
1. Hand-sampling of the crude-ore feed from the crushed-ore bins to the shaker screen.
2. The machine-sampling of the trommel undersize from the rolls (at the time the second hutch of the jig was returned to the jig elevator).
3. By computing the value of the crude ore from the various products produced.

1. The first method—*i.e.*, hand-sampling of the crude ore—was found to give erratic results.

2. The machine sample agreed closely with the crude-ore sampling plant, but at times a good deal of trouble was experienced, due to chips of wood getting across the slots on the cones of the machines.

3. The method of computing the crude ore from the products agreed closely with the crude-ore sampling mill.

D—ON CONCENTRATI



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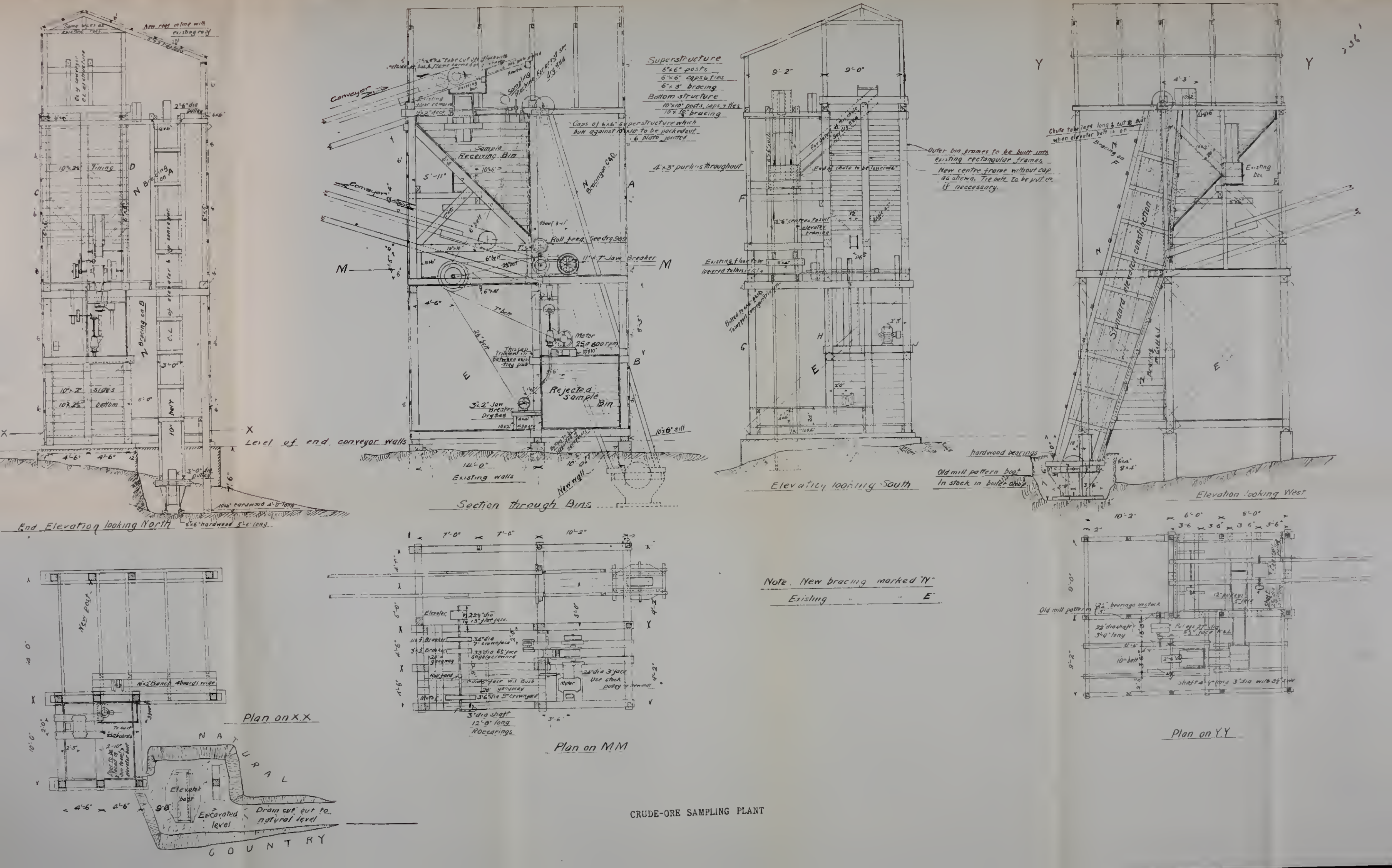
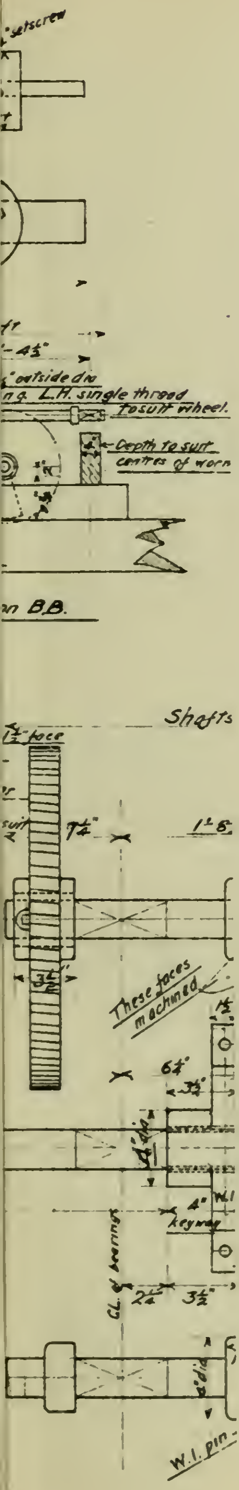

End Elevation looking North
Section through Bins
Elevation looking South
Elevation looking West
Plan on X.X
Plan on M.M
Plan on Y.Y
Superstructure
6"×6" posts
6"×6" caps & ties
6"×3" bracing
Bottom structure
10"×10" posts, caps, & ties
10"×3" bracing
Caps of 6x6" superstructure which butt against 10"x10" to be packed out, 6 plate jointed
4"×3" purlins throughout
Outer bin frames to be built into existing rectangular frames
New centre frame without cap as shown. Tie bolt to be put in if necessary.
Note. New bracing marked "N"
Existing " " "E"
Conveyor
Sample Receiving Bin
Rejected Sample Bin
Roll feed. See drg 989
11"×7" Jaw Breaker
3"×2" Jaw Breaker Drg 848
Motor 25 H.P. 600 R.P.M.
Level of end conveyor walls
Existing walls
New wall
10"×6" sill
Standard elevator construction
hardwood bearings
Old mill pattern boot In stock in boiler shop
Existing box
Chute to be left long & cut to suit when elevator belt is on
N A T U R A L C O U N T R Y
Elevator boot
Excavated level
Drain cut out to natural level
New post
10"×3" Bench 4 boards wide
3" dia shaft 12'-0" long Roc carings
Shaft 4'-7" long 3" dia with 3½" ...
Old mill pattern 2½" bearings in stock
M
X
Y

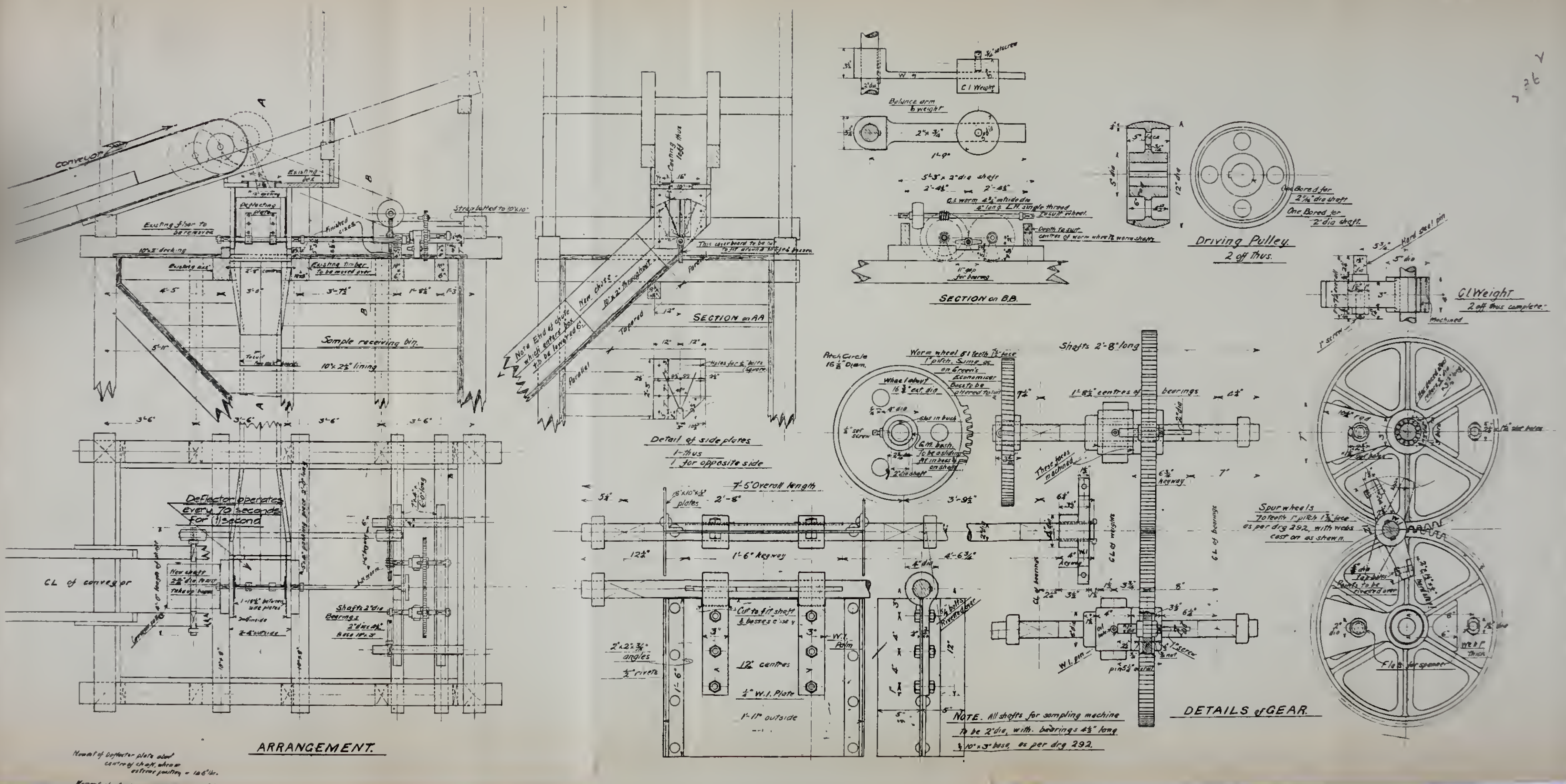
CRUDE-ORE SAMPLING PLANT

WAINWRIGHT &



ll shafts for sampling
"dia, with bearings 4
base, as per drg 29

FIG 8.



DETAILS OF SAMPLER

READ—ON CONCEN

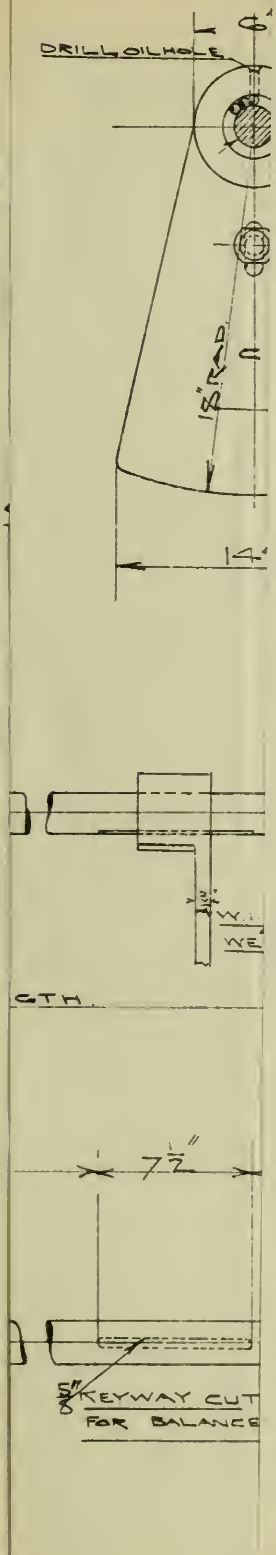
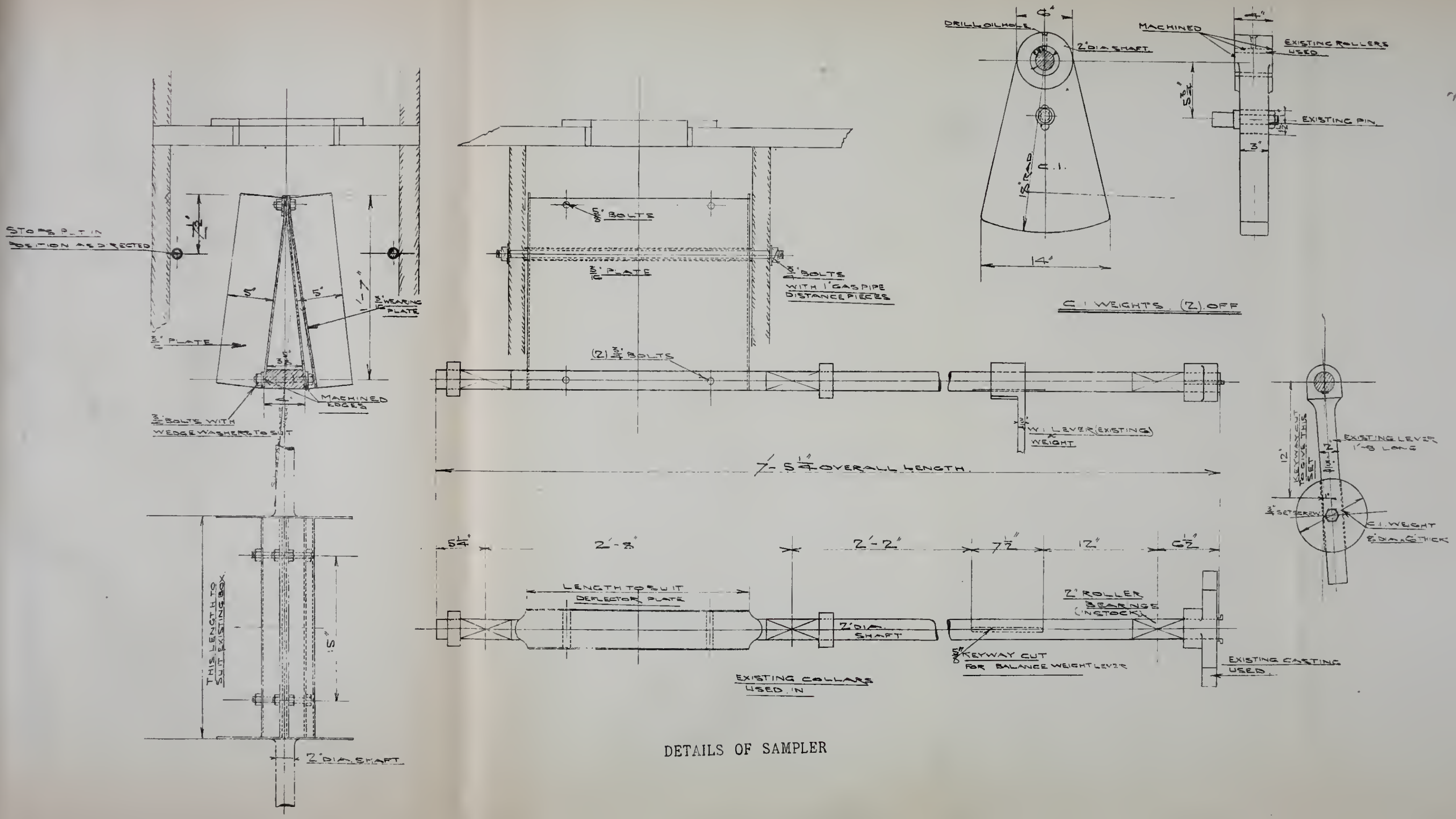


FIG 7.



DETAILS OF SAMPLER

Crude-Ore Sampling Plant.—This is placed at the discharge end of the lower crude-ore conveyor belt. The apparatus first used is illustrated in Figs. 5, 6 and 7; this has since been modified, whereby the deflecting plate of the sample cutter is returned to its normal position by a spiral spring instead of depending upon the second alling weight to do so. This deflection of the ore-stream occurs once every 70 seconds, and gives approximately 1/200th part of the total crude ore. The falling weight is swung on a shaft, and is raised by a pin in a spur-wheel. When the weight has reached the top position t topples over, and in doing so operates the deflection plate.

The sample collected in the sample bin during the 24 hours is fed during the day shift through an 11-in. x 7-in. jaw-crusher, reducing it to about 20 mm. maximum size. The crushed ore falls through a 4-in pipe and over a Vezin sampler, which takes out a $\frac{1}{10}$ cut, giving approximately $\frac{1}{2000}$ of the ore milled.

The sample from the Vezin passes to a 2½-in. x 6-in. roll jaw-crusher, which reduces it to 10 mm. gauge. This material is emptied on to the sample room floor, and at the end of the shift is cut down by a Jones riffle, with 1-in. spaces, until 56 lb. is left.

The 56-lb. sample is taken to the assay office, where it is prepared r assay. All rejects from the sample are returned to the top conveyor belt by a bucket elevator.

MILLING PLANT.

The lay-out of the mill is in four sections, each capable of treating 310 tons crude ore per day of 24 hours.

Each section is identical as regards flow and machinery, except in the case of the No. 1 section, which has one 14-in. x 4 ft. 7⅛ in. Krupp tube mill replacing five grinding pans. The following description gives the plant equipment for a single section only:—

Coarse Crushing.—The crude ore is drawn from the bin through a cast-iron rack and pinion door by a roller feeder running at 1.8 r.p.m., and falls on to a shaker, where water is added. Portion of the shaker bottom—3 ft. x 1¼ ft.—is fitted with 4 mm. round-hole punched plate. The shaker is set at an angle of 10°, and makes 162 strokes per minute. The end of the shaker is sectionalized for easy removal when roll repairs are necessary.

The fines in the crushed ore as it flows over the shaker pass through the 4 mm. punched plate on to the trommel apron, where it joins the undersize from the trommel, and is subsequently elevated to the jig screens.

The oversize from the shaker is fed to a pair of rolls.

The sizing of the ore issuing from the crushed crude-ore bins is as under:—

Grading Analyses of Crushed Crude Ore Feed to Shaker.

Mesh.	Aperture of screen. mm.	% weight.	ASSAY.			PROPORTION.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
19 mm. ..	19	50.3	12.7	6.0	12.0	44.1	42.2	43.1
5 mm. ..	5	27.3	15.4	7.3	14.7	28.9	27.8	28.6
5 mesh	2.540	2.5	13.9	8.3	15.1	2.4	3.0	2.7
8 ,,	1.574	2.2	13.1	8.6	16.9	2.0	2.6	2.7
10 ,,	1.270	.9	13.2	7.9	17.0	.8	1.0	1.0
20 ,,	.635	9.0	17.7	8.9	18.5	11.0	11.3	11.9
40 ,,	.317	1.7	18.3	8.9	19.0	2.1	2.1	2.3
60 ,,	.211	1.2	19.1	9.3	17.2	1.6	1.6	1.5
80 ,,	.157	2.3	20.3	11.2	17.5	3.2	3.6	2.9
100 ,,	.127	.8	19.9	11.5	17.4	1.1	1.3	1.0
150 ,,	.084	.8	21.7	13.2	17.5	1.2	1.5	1.0
—150 ,,	.084	1.0	22.6	14.5	18.0	1.6	2.0	1.3
		100.0	14.5	7.1	14.0	100.0	100.0	100.0

Grading Analyses Crude Ore Fed to Rolls.

——	% weight.	ASSAY.			PROPORTION.		
		% Pb	Oz. Ag.	% Zn.	% Pb.	% Ag	% Zn.
+19 mm.	59.7	12.7	6.0	12.0	54.7	54.5	54.5
5 mm.	37.1	15.4	7.3	14.7	41.3	41.1	41.4
—5 mm. ..	3.2	17.5	9.2	17.0	4.0	4.4	4.1
	100.0	13.9	6.6	13.2	100.0	100.0	100.0

Rolls.—On this mine the rolls are used to complete the reduction of the ore from 50 mm. gauge to 3 mm. One pair of rolls is used per section. The steel tyre or shell is 36 in. diam., with 18-in. face, held on coned centres by six tightening bolts. The set of rolls consists of one plain and one flanged shell, both of the same diameter, and kept in contact by rubber buffers. The rolls are gear-driven, and are provided with a back gear for driving the back roll; this back gear has one less tooth in the driven wheel in order to prevent corrugating. The speed of the rolls is 16 r.p.m. The capacity of each set of rolls is 265 tons of crude ore per 24 hours, crushed through 3 mm. The feed is distributed across the full face of the roll by the shaker.

The crushed ore from the rolls passes through a pair of cylindrical trommels, 6 ft. long, 2 ft. diam., covered with 3 mm. round-hole punched plate. These trommels are set at an angle of 15°, and are driven by a bevel gear at a speed of 32 r.p.m. The life of the punched plate is approximately 14 days.

The trommels divide the roll discharge into undersize and oversize. The oversize, or raffs, together with the second hutch of the jig, is returned to the rolls by a belt and bucket elevator. The undersize from the trommels, together with the shaker-screen undersize, passes to an elevator, and is delivered over two revolving screens at the head of the jig, which again classifies it into an undersize and an oversize. The oversize flows to the jig, while the undersize gravitates to the table section, and forms portion of the feed to the No. 3 and 4 rows of tables.

All launders carrying raffs have a 45° slope, and are lined with 2-in. angle iron transverse to the launder flow and spaced 12 in. apart to prevent scour on the launder, and so reduce cost of renewals.

The following is the grading and assay of the trommel oversize:—

Grading and Assay of Trommel Screen Oversize or Raffs (not including Second Hutch of Jig).

Mesh.	Aperture. mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+5 mm. ..	5.00	73.4	7.4	4.8	10.0	72.0	78.0	77.1
5 mesh ..	2.54	14.9	6.9	3.2	7.2	13.6	10.6	11.2
10 ,, ..	1.27	7.4	7.2	3.6	7.8	7.1	6.0	6.1
20 ,, ..	.635	2.3	9.0	4.8	11.0	2.8	2.4	2.6
40 ,, ..	.317	.7	15.5	5.0	13.7	1.4	.8	1.0
—40 ,, ..	—.317	1.3	16.3	7.8	14.6	3.1	2.2	2.0
		100.0	7.5	4.5	9.5	100.0	100.0	100.0

Jig and Raff Elevators.—There is one of each of these to each section. The elevators are typical of the whole mill; the gearing, framework, boots, hoppers, &c., are standardized.

Figs. 8, 9 and 10 give details of the elevators. The boots are of

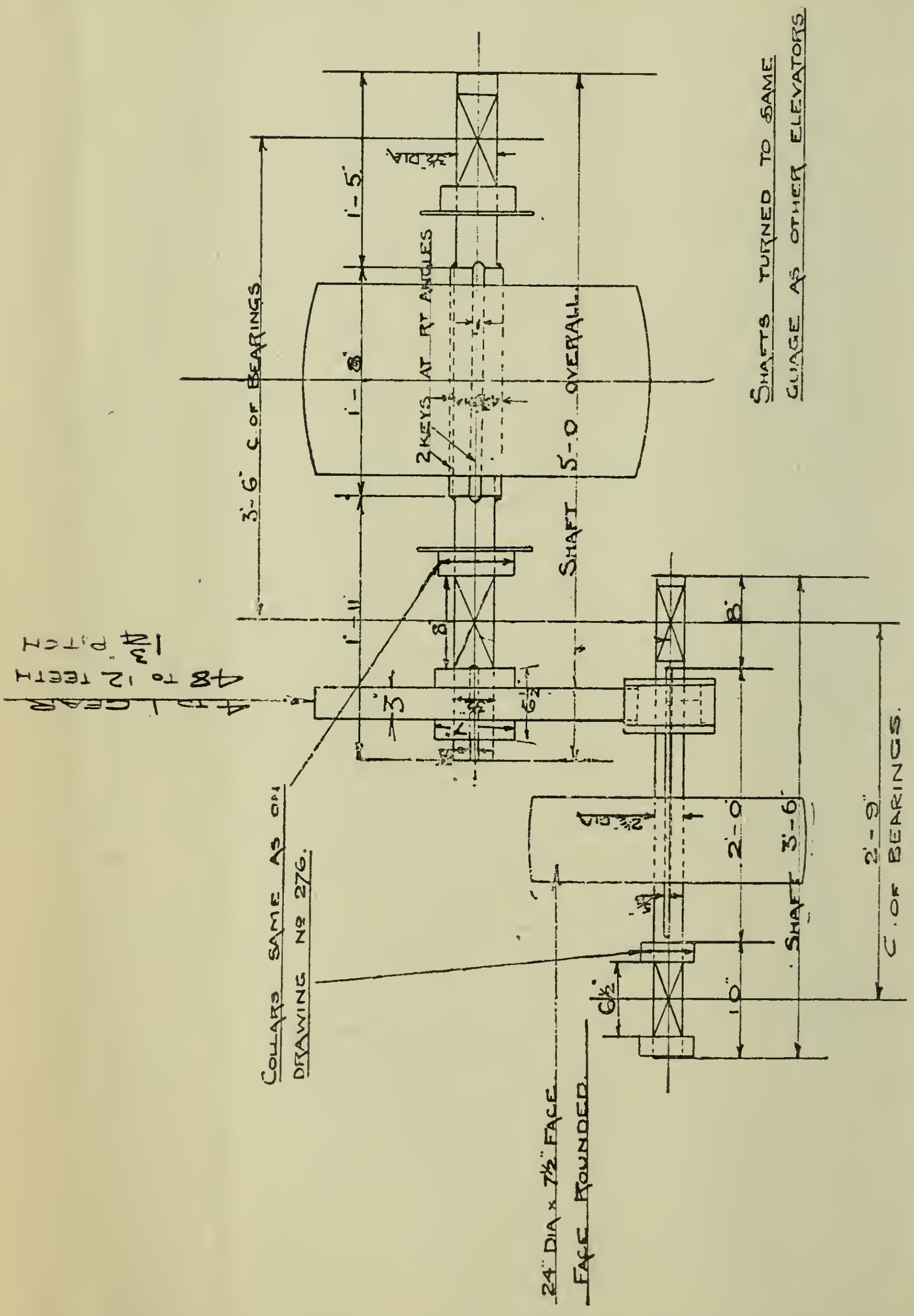
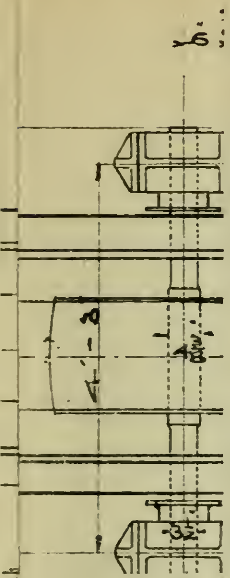


Fig. 10.
Elevator Top Pully and Driving Gear.

cast iron, and are fitted with a door at the side to permit removal of obstructions.

GHT & READ—(



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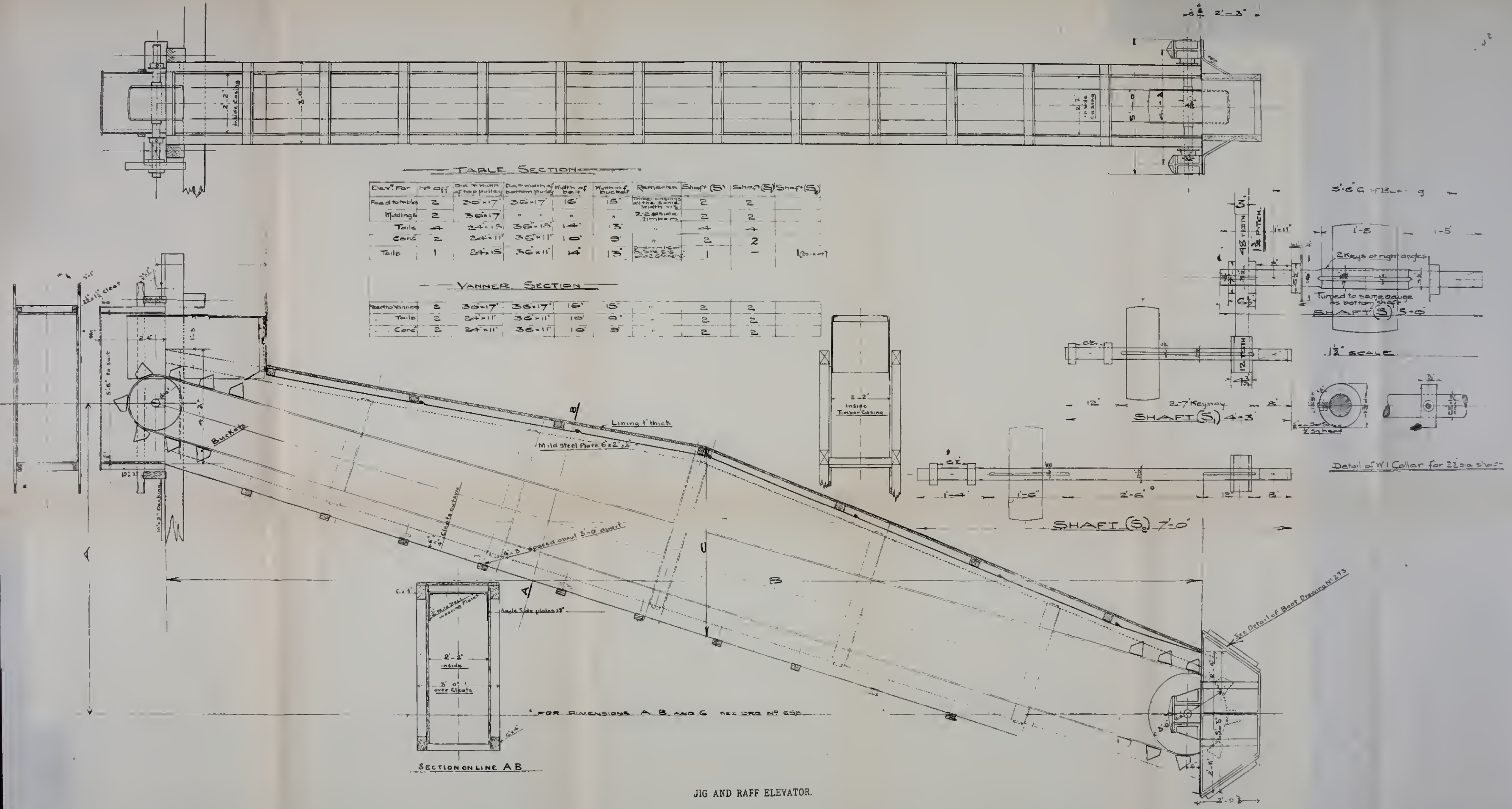

TABLE SECTION

Elev. For	No Off	Dia & width of top pulley	Dia & width of bottom pulley	Width of belt	Width of bucket	Remarks	Shaft (S)	Shaft (S1)	Shaft (S2)
Feed to table	2	30"×17"	36"×17"	16"	15"	Timber casings all the same width 4×3	2	2	
Middlings	2	30"×17	" "	"	"	2-2 inside timbers	2	2	
Tails	4	24"×15	36"×15"	14"	13"	"	4	4	
Conc	2	24"×11"	36"×11"	10"	9"	"	2	2	
Tails	1	24"×15	36"×11"	14"	13"	Dimensions of Cent. & Shoe E-C and 2 Channels	1	—	1 (20-0")

VANNER SECTION

Elev. For	No Off	Dia & width of top pulley	Dia & width of bottom pulley	Width of belt	Width of bucket	Remarks	Shaft (S)	Shaft (S1)	Shaft (S2)
Feed to Vanners	2	30"×17"	36"×17"	16"	15"	"	2	2	
Tails	2	24"×11"	36"×11"	10"	9"	"	2	2	
Conc	2	24"×11"	36"×11"	10"	9"	"	2	2	

JIG AND RAFF ELEVATOR.

READ—ON CONCENTRATIN

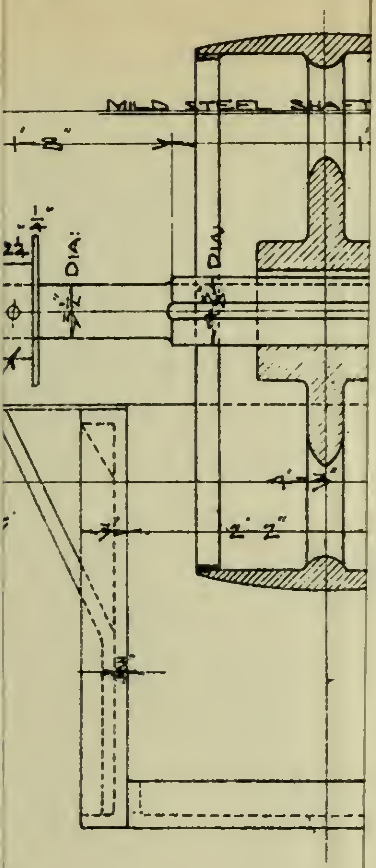

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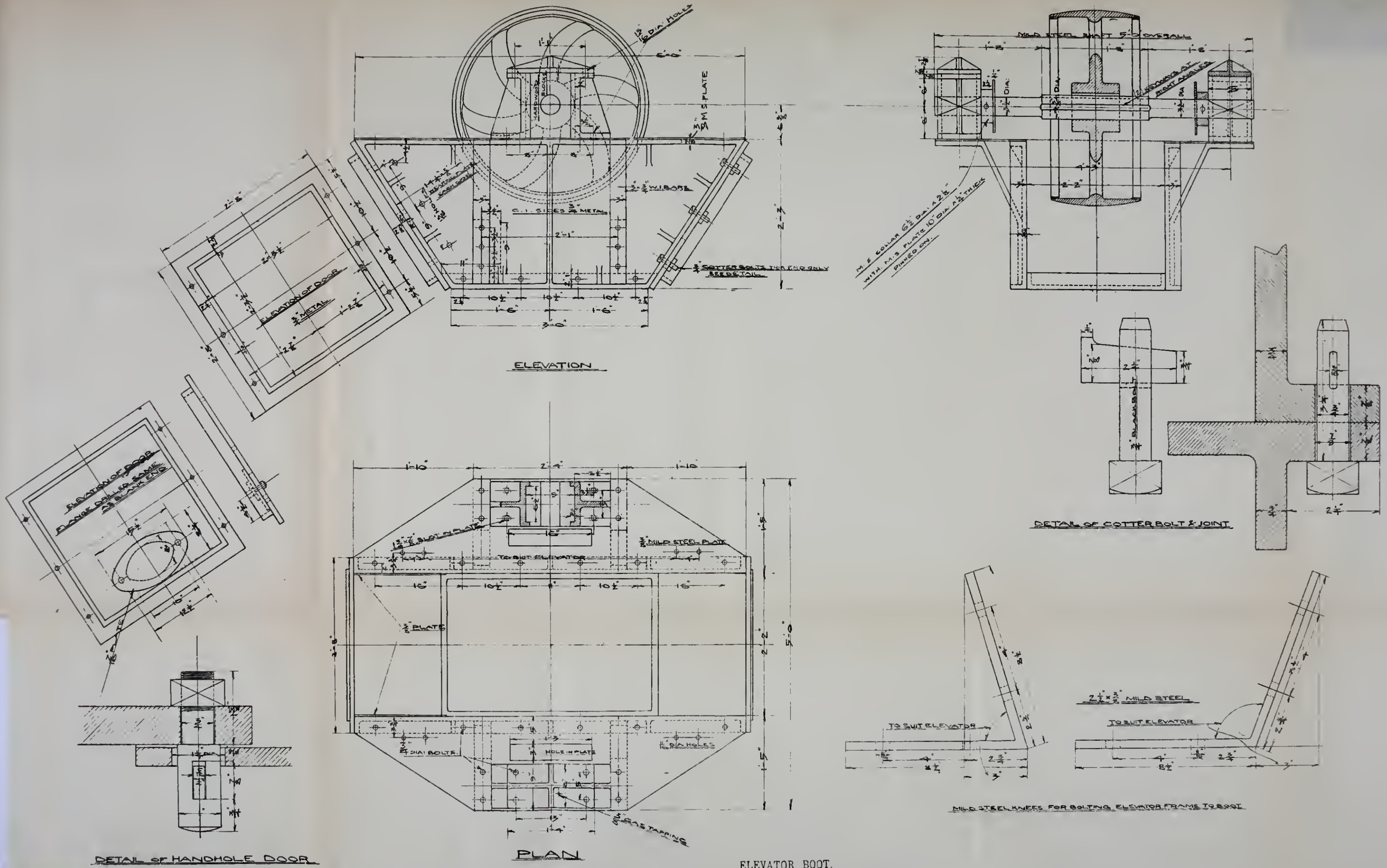
FIG. 9.



ELEVATOR BOOT.

The backs of the elevators are lined with 10-in. x 2-in. oregon, and nailed transverse across the back are strips of 3-in. x 2-in. hardwood faced by old balata belt to increase the life of the back.

The following are full particulars of these elevators:—

Name of elevator.	Width of belt.	Length of belt.	Belt centres	Width and pitch of buckets.		Speed of belt, ft. per min.	Diam. of top pulley.		Diam. of bottom pulley.		r.p.m. of top pulley.
	in.	ft.	ft.	in.	in.		ft.	in.	ft.	in.	
Jig ..	14	102	46¾	13	13	358	2	6	3	0	45½
Raff ..	16	88½	40	15	14	358	2	6	3	0	45½

To give a clean discharge of products it was in practice found that the distance of the discharge hopper lip from the centre of the top pulley shaft should be approximately six feet.

Screens Before the Jigs.—The jig feed elevators of each section deliver to a pair of revolving King screens, which are situated at the end of and above the jig. These are fed by a double discharge apron. All screens are 3 ft. wide, and are covered with 30-mesh brass wire-wove cloth. Each screen feeds its oversize to one side of the duplex May plunger jig, while the undersize passes to the third and fourth row of tables in the table section of the mill. The undersize from the screens amounts to approximately one-third of the total feed to the screens.

The following are the grading analyses of the feed and products of these screens:—

Grading and Analyses of Feed to Jig Screens (including Second Hutch from Jig).

Mesh.	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+ 10 ..	1.27	12.0	11.5	6.0	10.6	8.1	8.5	8.5
20 ..	.635	16.0	14.1	5.6	14.4	13.3	10.6	15.5
40 ..	.317	12.0	16.7	6.8	14.7	11.8	9.6	11.7
60 ..	.211	9.0	18.8	7.2	15.2	9.9	7.6	9.2
80 ..	.157	5.5	16.6	8.0	15.8	5.3	5.2	5.8
100 ..	.127	21.2	16.8	10.4	16.1	20.9	26.0	23.0
150 ..	.084	10.3	19.5	10.0	15.9	11.8	12.1	11.0
—150 ..	.084	14.0	23.0	12.4	16.4	18.9	20.4	15.3
		100.0	17.0	8.5	14.9	100.0	100.0	100.0

Grading Analyses, Oversize from Jig Screen (Feed to Jig).

Mesh.	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+ 10	1.27	18.0	10.1	5.4	11.0	11.1	14.8	14.4
+ 20	.635	30.5	15.5	5.8	13.5	28.8	27.0	29.9
40	.317	19.0	18.8	6.4	14.8	21.8	18.6	20.4
60	.211	7.5	19.6	6.6	14.0	9.0	7.6	7.6
80	.157	4.5	16.5	7.0	15.2	4.5	4.8	5.0
100	.127	5.0	15.1	7.0	15.4	4.6	5.3	5.6
150	.084	4.0	18.3	8.2	15.0	4.5	5.0	4.3
—150	.084	11.5	22.4	9.6	15.2	15.7	16.9	12.8
		100.0	16.4	6.5	13.8	100.0	100.0	100.0

Undersize from Jig Screens (Portion of Feed to Third and Fourth Row of Tables).

Mesh.	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+40	.317	9.0	14.4	5.6	14.8	6.9	5.2	8.5
60	.211	14.0	16.0	6.6	15.0	11.9	9.5	13.4
80	.157	11.0	16.4	8.6	16.0	9.6	9.7	11.2
100	.127	21.5	17.5	9.2	16.0	20.0	20.4	21.9
150	.084	12.0	18.8	10.0	15.9	12.0	12.4	12.1
—150	.084	32.5	23.0	12.8	15.9	39.6	42.8	32.9
		100.0	18.8	9.7	15.7	100.0	100.0	100.0

KING REVOLVING TROUGHED SCREEN.

This type of screen is extensively used throughout the mill. Fig. 11 shows complete details of its construction. A webbed cast-iron disc and an open ring form the two ends of the screen frame. These are joined together by twelve bolts through gas pipe distance

PRACTICE—BROKEN HILL SOUTH LIMITED. FIG 11.

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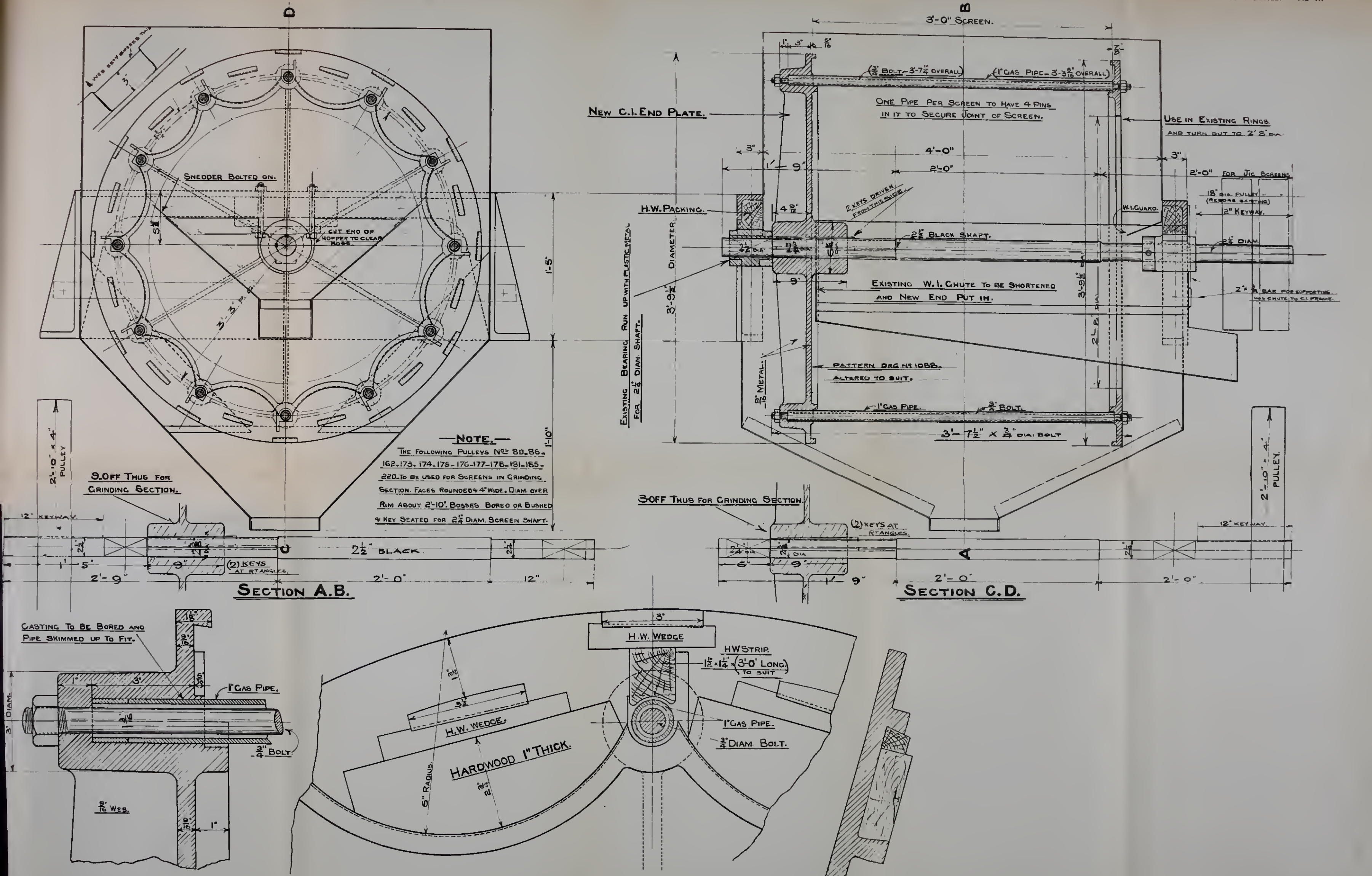
D
WEB BENT BEFORE TWO
3"
SNEDDER BOLTED ON.
CUT END OF HOPPER TO CLEAR BOSS.
3'-3" R.
1'-5"
1'-10"
—NOTE.—
THE FOLLOWING PULLEYS Nos 80-86-162-173-174-175-176-177-178-181-185-220-TO BE USED FOR SCREENS IN GRINDING SECTION. FACES ROUNDED & 4" WIDE. DIAM. OVER RIM ABOUT 2'-10". BOSSES BORED OR BUSHED & KEY SEATED FOR $2\frac{1}{4}$" DIAM. SCREEN SHAFT.
2'-10" × 4" PULLEY
9.OFF THUS FOR GRINDING SECTION.
12" KEYWAY
$2\frac{1}{2}$" BLACK
(2) KEYS AT RT ANGLES.
1'-5"
2'-9"
9"
2'-0"
12"
C
SECTION A.B.
B
3'-0" SCREEN.
($\frac{3}{4}$" BOLT - 3'-$7\frac{1}{4}$" OVERALL)
(1" GAS PIPE - 3'-$3\frac{9}{16}$" OVERALL)
ONE PIPE PER SCREEN TO HAVE 4 PINS IN IT TO SECURE JOINT OF SCREEN.
NEW C.I. END PLATE.
USE IN EXISTING RINGS AND TURN OUT TO 2'8" DIA.
4'-0"
2'-0"
1'-9"
3"
2'-0" FOR JIG SCREENS
18" DIA. PULLEY (REBORE EXISTING)
2" KEYWAY.
H.W. PACKING.
2 KEYS DRIVEN FROM THIS SIDE
W.I. GUARD.
$2\frac{1}{4}$" BLACK SHAFT.
$2\frac{1}{4}$" DIAM.
EXISTING W.I. CHUTE TO BE SHORTENED AND NEW END PUT IN.
2" × $\frac{3}{8}$" BAR FOR SUPPORTING W.I. CHUTE TO C.I. FRAME.
EXISTING BEARING RUN UP WITH PLASTIC METAL FOR $2\frac{1}{4}$" DIAM. SHAFT.
3'-$9\frac{1}{2}$" DIAMETER.
$\frac{9}{16}$" METAL.
PATTERN DRG No 1088. ALTERED TO SUIT.
1" GAS PIPE.
$\frac{3}{4}$" BOLT.
3'-$7\frac{1}{2}$" × $\frac{3}{4}$" DIA. BOLT
2'-8" DIA.
3'-$9\frac{1}{2}$" DIA.
3.OFF THUS FOR GRINDING SECTION.
(2) KEYS AT RT ANGLES.
12" KEYWAY.
2'-10" × 4" PULLEY.
A
1'-9"
2'-0"
2'-0"
SECTION C.D.
CASTING TO BE BORED AND PIPE SKIMMED UP TO FIT.
1" GAS PIPE.
$\frac{3}{4}$" BOLT.
3" DIAM.
$\frac{9}{16}$" WEB.
1"
3"
H.W. WEDGE
HW STRIP. $1\frac{1}{2}$" × $1\frac{1}{4}$" × (3'-0" LONG. TO SUIT)
1" GAS PIPE.
$\frac{3}{4}$" DIAM. BOLT.
H.W. WEDGE.
HARDWOOD 1" THICK.
6" RADIUS.

REVOLVING SCREEN.

G PRACTICE—BROKEN HILL SOUTH LIMITED. FIG 12.

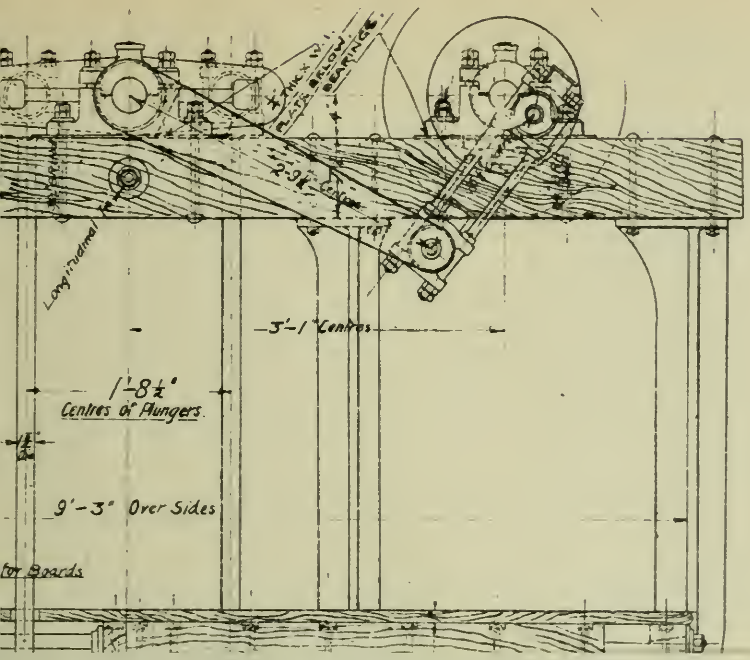

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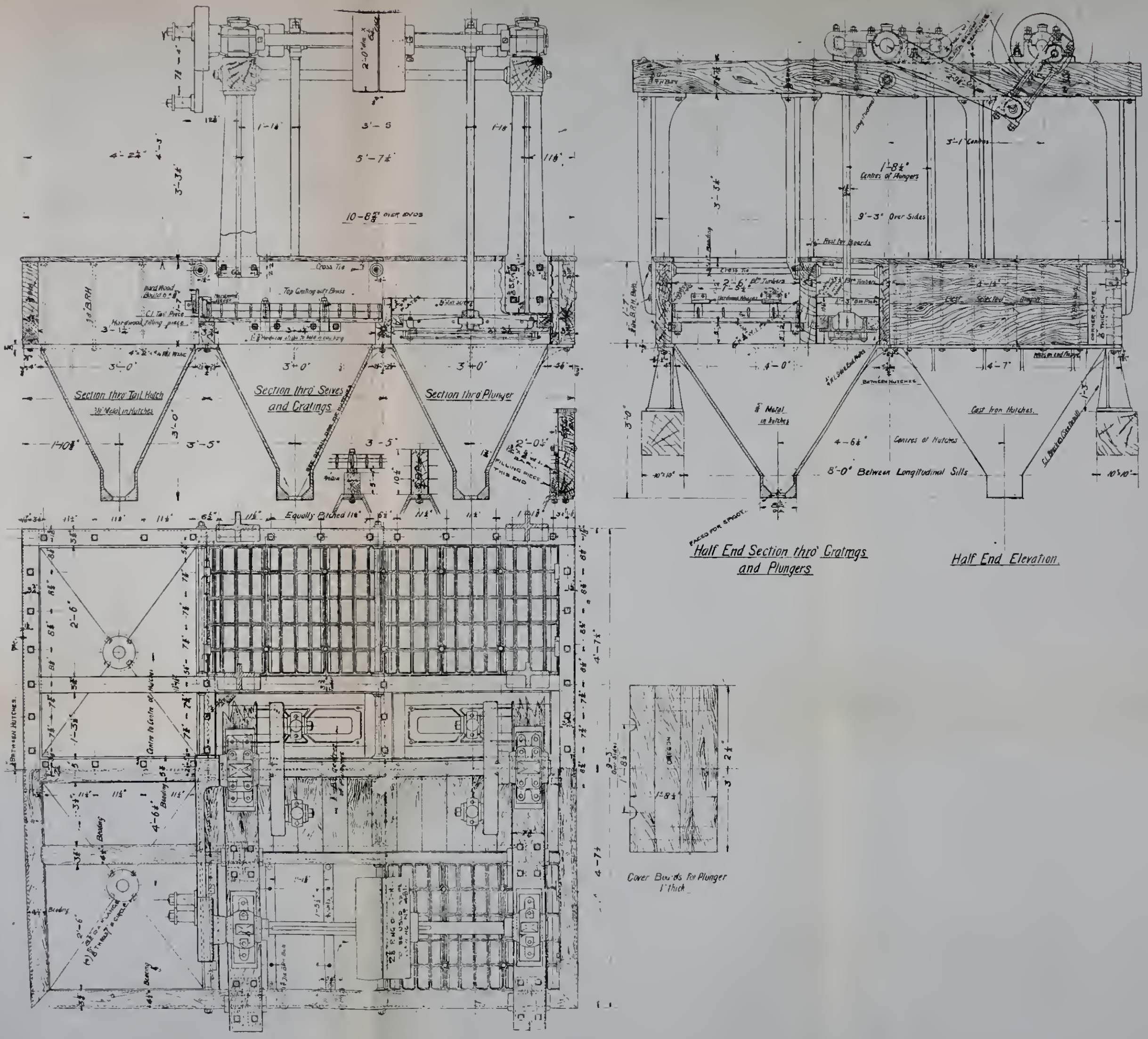
FIG 12.



MAY JIG.

pieces, extending between the frames. On the inside of each end are cast a number of lugs, as shown in the drawing. These lugs and curved bars serve to shape the screen cloth, when placed on the frame, into twelve troughs. Wooden blocks wedged in under the cast-iron lugs serve to hold the screen wire in position.

The solid end of the screen, which is also the driving end, carries the whole weight of the screen, and is cast with a heavy boss, strengthened with webs.

The shaft for driving the screens is 5 ft. 10½ in. long by 2½ in. diam. It passes through the machined boss of the webbed end, and is keyed in position. Ordinary 2½-in. plummer blocks serve as bearings for the shaft.

The whole screen is contained in a splash-proof wooden box, suitably arranged with discharge launders.

Secured to the hopper on the opposite end to the drive is a steel tray, which extends for the full length of the screen frame, and through the open end. The tray receives the screen undersize, and discharges it into its proper launder.

Situated a little above the top of the screen, and extending for its full length, is a wash-water spray pipe, which serves to wash the fines through the screen. A similar pipe is placed inside the screen, under the above-described tray, for washing off the oversize. The feed is distributed on the screen by means of a cast-iron apron.

The screen is driven by a 2½-in. belt, at 8 r.p.m., and requires a length of 12 ft. of brass wire screen cloth to cover the frame.

The quantity of spray water required per screen for washing the feed and for washing the binding out of the wire wove is 360 gal. per hour per screen.

JIGS.

Jigging.—Each section contains one May duplex three-compartment jig. Fig. 12 gives the general outlines of its construction. The following is a description of the jig :—

The jig consists of two independent jigs of three cast-iron hutches each, which are bolted on to a wooden frame, measuring 10ft. 9½ in. long by 9 ft. 3 in. wide over all. Each hutch is divided into a sieve compartment and a plunger compartment, excepting the last, which is a tailings hutch.

The outer compartments, in which the jig sieves are fixed, are 2 ft. 6⅜ in. wide ; the two plunger compartments are 1 ft. 3½ in. wide.

Each of the above four-sieve compartments is subdivided into three equal lengths by cross timbers. On the head end of the jig, or first hutch, the sieve frames are held down with two small iron brackets, under which is driven a hardwood wedge. The second hutch sieves are held in position by a hardwood wedge, driven under the lugs of a cast-iron angle-plate, bolted to the hutch. At the back of the angle-plate, between the second and third hutches, are bolted two small iron brackets to hold the adjustable tail-board. The depth of adjustment depends on the load required on the sieves. The third hutch on either side is for tailings.

Jig Sieves.—The bottom sieve frames are made of cast iron, 2 ft. 6 in. x 13½ in. by 1½ in. deep, with openings 5 in. x 2½ in.

The punched plate or screen wire used for holding the ragging and forming the bed of the jig is laid between the bottom and brass top sieve frames. The frames are then lightly caulked with oakum.

The top sieve frames are made of brass in order to avoid breakage when pulling down on the bottom frame, or when removing for renewal of sieves. They measure 2 ft. 6 in. x 13½ in. x 1¾ in. deep.

Each jig requires 24 frames—three top and three bottom frames for each hutch.

A layer of "ragging," approximately 1½ in. thick, made of 5/16-in. round bar-iron, cut into lengths from 5/16 in. to ⅜ in., is placed on the sieves to form a bed. The depth of the bed is varied to suit the class of ore to be treated and the grade of concentrate required.

Plungers.—Each jig has four plungers, two on either side corresponding to the hutch. The plunger is constructed of cast iron, with a boss bored to a taper, to suit the end of the plunger rod. The plunger measures 2 ft. 11½ in. x 1 ft. 1¾ in., and is fitted with the usual clack board. The action of the plunger is to cause a pulsating action under and through the ore-bed.

Motion Gear.—The motion gear is placed on eight cast-iron standards, which carry the timbers to which the gear is bolted. The driving shafts are 7 ft. 3 in. long, 3 in. diam., with fast and loose pulleys. On the driving shaft is a 15-in. diam. disc with a 6-in. x 1⅛-in. slot, in which a cone-headed bolt carrying a reel fits. The reel acts as a crank pin for the connecting rods to the rocker shaft; the slot serves for adjusting the stroke of the jig.

The rocker shaft is placed over the centre of the jig. It is 7 ft. long x 3½ in. diam. To it is keyed two cast-iron arms, or rockers, each 2 ft. 8 in. long. The rocker arms are slotted at the ends, to take a square-headed bolt, carrying a cast-iron reel (similar to those on the disc). The plunger rods are carried on the rocker arm reels. The slots in the rocker arm permit each plunger to be given its proper stroke.

Spigots.—The products made by the jig are discharged from the hutches by a spigot, which hinges from a cast-iron seat, and is bolted to the bottom of the hutch. Attached to the end of the lever of the spigot is a ¼-in. rod, long enough to reach to the floor above, thus enabling the jig attendant to operate the spigot from the jig floor for cleaning purposes. The holes in the spigots are as follows:—

1st hutch on lead concentrate, ½ in. diam.
2nd hutch on middling, ½ in. diam.
3rd hutch on tailing, 1⅛ in. diam.

The Practice of Jigging.—The feed to the jig consists of the jig screen oversize. Each screen delivers the oversize to its corresponding side of the jig. The material travels slowly along towards the tail of the jig, forming a bed of material on the sieves. The movement of the pulp is caused by the flow of added water and the pulsations of the plunger. The ore forms a bed on the ragging of the jig sieves, and each stroke of the plunger causes a pulsating action through the ore-bed, disturbs it, and allows the mineral with the highest gravity to sink, and finally drop through the ragging and sieve into the hutch below, whilst the mineral with the lower gravity flows over the tail-board into the tail hutch.

Three products are made by these jigs—

1st hutch, lead concentrate, which is stored in bins.
2nd hutch, lead middling, which is returned to the rolls.
3rd hutch, lead-zinc tailing, which gravitates to the grinding pans, and is required for subsequent table treatment.

The jig has a capacity of 12 tons per hour, and makes 184 strokes per minute.

The following are the gradings and assays of the products made by the jigs:—

Grading Analyses of Jig Products.

No. 1 Hutch Jig Concentrate.

Mesh.	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+10	1.27	3.0	52.3	21.4	12.5	2.3	2.9	5.2
20	.635	25.0	65.1	22.4	9.3	24.2	25.0	32.6
40	.317	28.0	70.7	23.2	5.9	29.4	29.0	23.1
60	.211	16.0	71.3	23.2	5.6	17.0	16.5	12.5
80	.157	8.0	69.1	22.0	6.1	8.2	7.8	6.8
100	.127	6.0	61.1	20.6	6.4	5.5	5.5	5.4
150	.084	7.0	64.9	21.4	7.2	6.8	6.7	7.0
—150	.084	7.0	63.7	21.2	7.6	6.6	6.6	7.4
		100.0	67.2	22.4	7.1	100.0	100.0	100.0

No. 2 Hutch Jig Middling Returned to Rolls with Raffs.

+10	1.27	5.0	34.8	15.0	22.0	4.6	4.8	6.0
20	.635	22.0	33.8	15.0	22.0	19.4	21.5	26.2
40	.317	26.0	35.0	13.8	18.3	23.8	23.3	25.8
60	.211	14.0	36.6	13.4	18.0	13.4	12.3	13.7
80	.157	9.0	36.8	14.2	17.3	8.6	8.3	8.4
100	.127	4.0	38.6	15.0	17.0	4.0	4.0	3.7
150	.084	6.0	46.0	18.2	16.2	7.2	7.0	5.3
—150	.084	14.0	52.0	20.6	14.4	19.0	18.8	10.9
		100.0	38.3	15.3	18.4	100.0	100.0	100.0

No. 3 Hutch Jig Tail—Feed to Regrinding Pans.

+40	.317	63.8	6.7	3.7	12.8	56.1	55.6	56.0
+60	.211	14.5	5.7	3.3	17.3	10.8	11.0	17.2
80	.157	5.3	6.4	3.7	18.3	4.4	4.5	6.6
100	.127	2.4	7.2	4.1	18.7	2.3	2.3	3.1
150	.084	2.6	8.4	4.5	18.8	2.9	2.7	3.3
—150	.084	11.4	15.7	8.8	17.7	23.5	23.6	13.8
		100.0	7.6	4.3	14.6	100.0	100.0	100.0

REGRINDING.

Regrinding Jig Tailing.—The jig tailing is ground in closed circuit with screens, as follows :—The tailing from the jig flows to a row of 4-in. to 5-in. Forwood Down grinding pans in parallel, and are ground and elevated to a set of four revolving screens, fitted with 16-mesh brass wire cloth.

The oversize is returned to a second row of four 5-ft. pans, reground, and elevated to the screens. The screen undersize gravitates to the distributing box, feeding the Nos. 1 and 2 rows of tables. The grinding pans run at 55 r.p.m. The shoes and dies are made of hard iron, cast locally.

In one section a 14 ft. x 4 ft. 7$\frac{1}{8}$ in. diam. Krupp tube mill is operated in place of five of the grinding pans. The tube mill runs at 28 r.p.m. Both Danish and South Australian (Mount Gambier) flints are used for grinding purposes.

The following are the grading analyses and assay of the screen discharge after passing through the grinding pans :—

Grading Analyses of Pan Screen Discharge—Partial Feed to Tables.

Mesh.	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+40 ..	.317	34.4	3.5	2.3	11.6	16.0	18.4	27.2
+60 ..	.211	16.0	4.5	2.7	15.6	9.4	10.0	17.0
+80 ..	.157	6.9	5.1	3.1	16.6	4.6	4.9	7.8
+100 ..	.127	5.4	5.1	3.9	16.8	3.6	4.9	6.2
+150 ..	.084	11.0	9.1	5.0	16.6	13.2	12.8	12.4
−150 ..	.084	26.3	15.4	8.0	16.4	53.2	49.0	29.4
		100.0	7.6	4.3	14.6	100.0	100.0	100.0

TABLE SECTION.

Equipment.—The tables, with their attendant elevators, are housed in a separate building from the crushing and jigging sections. It is divided into four sections, with elevators common to two sections of the tables. It contains 96 Card-Wilfley-type tables, arranged in six rows, each containing sixteen tables. The first two rows—32 tables—treat the grinding pan screen undersize and portion of the middling from all tables. The third and fourth row—32 tables—treat the jig screen undersize, together with a portion of the middling from all tables. The fifth and sixth rows are re-treat tables for quartz and slime products made on the previous four rows of tables.

The products made by the tables are :—

No. of row.	
1 and 2	Lead concentrate, lead-zinc middling, zinc tail, quartz tail and slime.
3 and 4	Lead concentrate, lead-zinc middling, zinc tail, quartz tail and slime.
5	Lead-zinc middling, zinc tail, quartz tail and slime.
6	Lead concentrate, lead-zinc middling, zinc tail and slime.

All of the table decks, which are 14 ft. long x 6 ft. wide, are constructed of redwood screwed to oregon frames. The 64 tables of the first to fourth rows have a tapered groove ⅝-in. deep at the feed end, tapering to 1/16 in. at the head end, and spaced 2½ in. apart over the full width of the table.

The 32 tables working on the quartz screen and slime products have tapered grooves extending on the upper or feed side of the table from the feed end of the table for a length of 6 ft., and then gradually lengthen out until on the bottom side of the table the grooves extend the full length.

The tables are mounted on 24 double 3 in. x ¼ in. stringybark battens bolted to the frame of the table top and to an angle cleat on the floor.

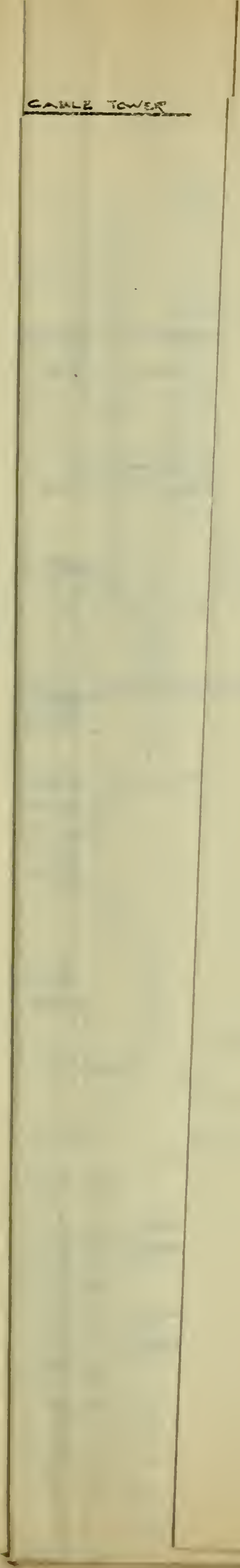
All tables are adjusted to the following :—

In lengths—level.
In width—fall of 1¾ in. on the first to fourth rows.
fall of 1½ in. on the fifth to sixth rows.
Length of stroke—¾ in. on the first to fourth rows.
½ in. on the fifth to sixth rows.
Speed—297 r.p.m. on the two strokes.

Elevators.—One each of the following elevators are common to each double section of tables :—Lead concentrate, middling, zinc tailing, quartz tailing, slime tailing.

The boots of these elevators are placed in a long concrete pit. All the elevators are of standard design. The full particulars are as follows :—

SOUTH LIMITED. FIG 13.



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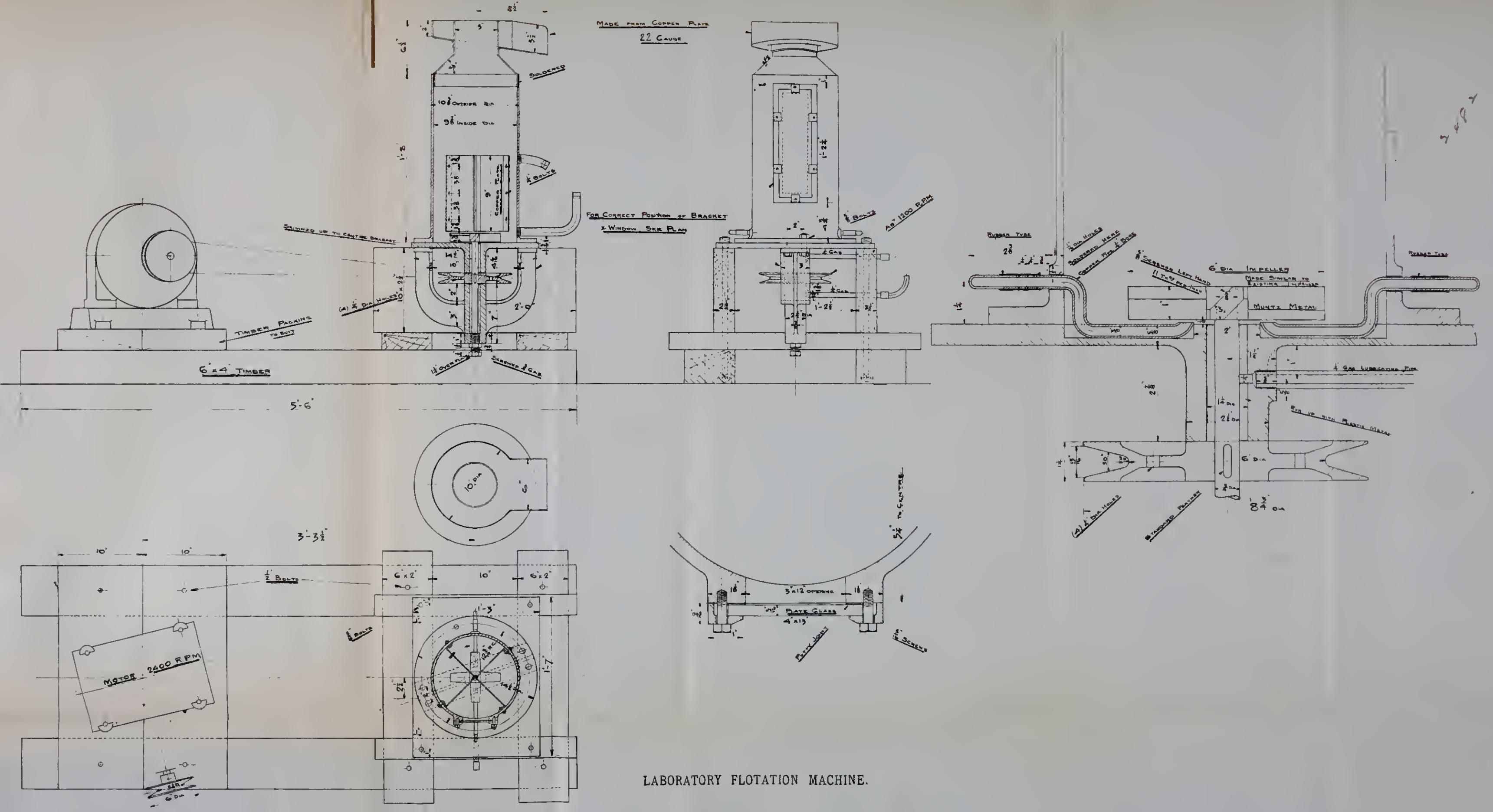


LABORATORY FLOTATION MACHINE.

Table of Mill Elevators.

Elevator.	Width fo bucket.	Pitch of bucket.	Width of belt.	Diam. of top pulley.	Revs. of top pulley.	Belt speed, r. p. m.	Centre of top to centre of bottom pulley.	Length of belt.	Diam. of bottom pulley.
	in.	in.	in.	ft. in.			ft. in.	ft. in.	ft.
Screens (4) ..	15	14	16	2 6	45.4	358	40 0	88 6	3
Table middling (2) ..	15	12	16	2 6	58	455	45 0	98 6	3
Table tail (2) ..	15	12	16	2 6	58	455	52 9	114 0	3
Table zinc (1) ..	15	12	16	2 0	58	364	56 3	120 0	3
(1) ..	15	12	16	2 0	58	364	53 6	115 0	3
Table conc. (2)	13	14	14	2 0	58	364	59 3	127 0	3

Settlers.—Each section of the mill has two settlers for separating the fine slime from the sand. This sand unavoidably flows from the tables with the slime. These settlers are V-shaped, 14 ft. long by 6 ft. high, constructed of 10 in. x 2 in. oregon, and provided with five discharge spigots and an overflow.

Practice of Table Treatment.—The pan screen undersize of each section flows to a distributing box; this box is fitted with a rotary distributor (Fig. 15 shows details of the apparatus), which divides the feed so that it runs evenly to eight of the tables (four on the first and four on the second row). Wash water is added on the upper side of the tables as required, and five products are made, as follows:—

—	Assay.		
	% Pb.	Oz. Ag.	% Zn.
1. Lead concentrate	63.8	23.0	7.8
2. Lead zinc middling	14.0	7.6	23.0
3. Zinc tailing	2.8	3.0	16.5
4. Quartz tailing	2.0	2.0	8.4
5. Slime tailing	9.7	7.0	14.0

The lead concentrate is elevated to wooden storage bins, drained, and railed to the smelters. The middling product is elevated and re-treated on the first to fourth row of tables.

Zinc tailing is elevated to the zinc storage bins, where it is drained, and railed to the zinc flotation plant of the Amalgamated Zinc (De Bavay's) Ltd.

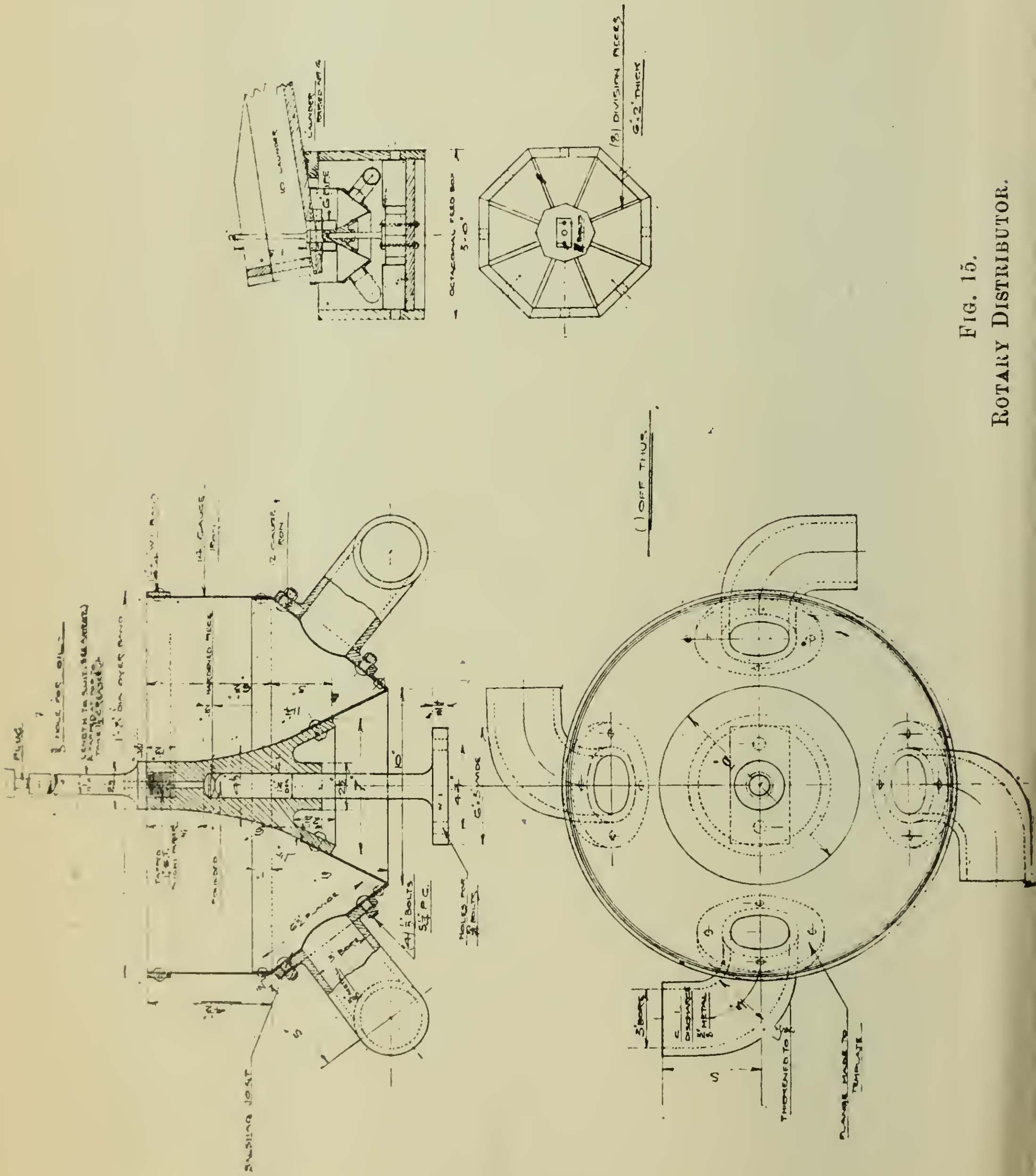


Fig. 15.
Rotary Distributor.

The quartz tailing is elevated and delivered over two revolving screens, fitted with 24-mesh brass wire cloth, running at 8 r.p.m.

The oversize and undersize are separately treated on the fifth and sixth rows of tables.

The slime product from the end of all the tables carries some quartz tails with it. This is settled out in V settlers, and the first two spigots returned to the quartz tailing elevator and sent to the 20-mesh screens ; the remaining three spigots are then elevated into cones, where they join the quartz screen undersize, and are treated on the sixth row of tables.

The fine slime overflow from the V settlers gravitates to the main slime launder running to the slime flotation plant, or to slime settling pits if the flotation plant is stopped.

The undersize from the jig screens, together with a portion of returns from all tables in the mill, is fed on to the third and fourth rows of tables in a similar manner to the pan screen undersize.

The products made are :—

—	Assay.		
	% Pb.	Oz. Ag.	% Zn.
Lead concentrate..	65.0	23.9	7.9
Lead zinc middling	27.2	13.6	22.0
Zinc tailing	4.0	4.4	19.0
Quartz tailing	2.3	2.3	12.0
Slime tailing	12.1	8.0	13.6

These various products follow the same channel for disposal as those from the first and second rows of tables.

Quartz Tailing Treatment.—The object of this treatment is to eliminate a valueless quartz product and to increase the zinc product, which is payable for flotation treatment.

The quartz tailing is divided into undersize and oversize by screens, as outlined above. The oversize is fed on to the fifth row of tables ; the products formed assay as follows :—

—	Assay.			Disposed of.
	% Pb.	Oz. Ag.	% Zn.	
Zinc middling and tail	3.0	3.2	13.2	De Bavay.
Quartz tailing	1.5	1.5	5.8	Filling underground.
Slime	11.0	7.6	13.4	Slime flotation plant.

The undersize from the quartz screens, together with the thickened pulp from the V settlers, is further de-watered in 4 ft. 6 in. diam. cones. The underflow from each cone distributes into the feed boxes of a pair of tables. The overflow joins the main launder to the slime flotation plant, or slime settling pits.

The products made on the undersize tables are :—

—	ASSAY.		
	% Pb.	Oz. Ag.	% Zn.
Lead concentrate	52.8	20.0	12.7
Lead zinc middling	8.7	8.0	27.2
Zinc tailing	2.9	2.5	14.0
Slime tailing	8.8	6.6	13.0

These products are disposed of as in the first to fourth rows table products.

The final products delivered from the table section are :—Lead concentrate, zinc tailing, quartz tailing, slime tailing.

The following tables show the grading analyses and assay of the final products made :—

Grading Analyses Table Concentrate.

Mesh.	Aperture in mm.	% weight.	ASSAY.			PROPORTION.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+ 20 ..	.635	2.0	28.6	16.6	18.9	0.9	1.4	4.7
40 ..	.317	7.5	61.2	22.0	10.5	7.1	7.0	10.2
60 ..	.211	14.0	70.6	24.8	6.9	15.3	14.9	12.2
80 ..	.157	7.2	70.4	24.0	7.0	7.8	7.4	6.4
100 ..	.127	5.5	68.4	23.6	6.3	5.8	5.6	4.4
120 ..	.107	23.5	65.6	23.6	7.5	23.8	23.7	22.4
150 ..	.084	5.0	60.8	23.5	8.3	4.7	5.0	5.3
−150 ..	.084	35.3	63.4	23.2	7.7	34.6	35.0	34.4
		100.0	64.7	23.4	7.9	100.0	100.0	100.0

Grading Analyses—Zinc Tailing.

Mesh.	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+40 ..	.317	32.5	3.0	2.4	15.4	30.4	23.8	30.1
60 ..	.211	22.5	2.0	2.6	16.0	14.3	17.9	21.6
80 ..	.157	9.5	2.5	2.6	17.0	7.4	7.5	9.7
100 ..	.127	8.0	2.3	3.4	18.3	5.7	8.3	8.8
120 ..	.107	12.5	2.3	3.4	19.2	8.9	12.9	14.5
150 ..	.084	.5	2.1	3.2	18.4	.3	.5	.5
−150 ..	.084	14.5	7.3	6.6	17.0	33.0	29.1	14.8
		100.0	3.2	3.3	16.6	100.0	100.0	100.0

Grading Analyses—Quartz Tailing.

+40 ..	.317	71.0	1.0	1.0	4.6	47.0	48.9	56.8
60 ..	.211	11.5	0.7	.8	4.9	5.4	6.4	9.8
80 ..	.157	3.5	0.7	.7	4.9	1.6	1.7	3.0
100 ..	.127	2.0	0.8	.8	6.0	1.1	1.1	2.1
120 ..	.107	.8	0.9	2.0	6.8	.4	1.1	1.0
150 ..	.084	1.0	0.9	2.0	9.4	.6	1.4	1.6
−150 ..	.084	10.2	6.5	5.6	14.5	43.9	39.4	25.7
		100.0	1.5	1.5	5.8	100.0	100.0	100.0

Grading—Slime Tailing.

+60 ..	.211	3.5	2.0	0.7	3.6	.7	.4	1.0
100 ..	.127	5.1	2.0	1.3	5.6	1.0	.9	2.1
150 ..	.084	4.5	2.6	1.4	6.6	1.1	.9	2.2
200 ..	.063	1.0	2.4	1.4	8.0	.2	.2	.6
−200 ..	.063	85.9	11.5	7.9	14.6	97.0	97.6	94.1
		100.0	10.2	7.0	13.3	100.0	100.0	100.0

The following table shows the total tonnage and segregation of the various products, dating from the introduction of quartz screens in June, 1911, to May, 1919 :—

Table No. III.

—	Tons.	% Weight.	Assay.			Proportion.		
			% Pb.	Oz.Ag.	% Zn.	% Pb.	% Ag.	% Zn.
Jig lead concentrate	180,482	8.35	67.2	22.4	7.1	38.7	26.7	4.4
Table lead concentrates ..	180,305	8.34	64.7	23.4	7.9	37.2	28.0	4.8
Total lead concentrates ..	360,787	16.69	65.9	22.9	7.6	75.9	54.7	9.2
Zinc tailing ..	1,373,943	63.59	3.2	3.3	16.6	14.0	30.2	75.6
Quartz tailing ..	135,569	6.27	1.5	1.5	5.8	.7	1.5	2.6
Slime	290,610	13.45	10.2	7.0	13.3	9.4	13.6	12.6
Crude ore ..	2,160,909	100.0	14.5	7.1	14.0	100.0	100.0	100.0

Comparing the above table with Table No. II., relating to 1911, the altered system has resulted in giving—

(1) Increased lead and silver recovery.

(2) Increased production of zinc tailing for zinc flotation treatment and a reduction in waste tailing.

GENERAL.

Storage of Product.—The whole of the lead concentrate and zinc tailing is stored and drained in wooden bins situated between the jig and table sections.

Concentrate Storage.—A row of ten bins—eight holding 320 tons each, two holding 190 tons each—built of oregon, and with sloping bottoms, is used. Each bin is provided with three cast-iron doors, operated by rack and pinion, for discharging purposes. The bins are all provided with a baffle board 6 in. inside of the overflow lip, to retain any fine lead concentrate floating on the surface of the water. These storage bins (concentrate and tailing) are provided with filter bottoms. The arrangement is as follows:—Each bin has a slope bottom, and, for discharging the drained product, the front of the bin is provided with three cast-iron doors operated by a rack and pinion. On the inside of the bin, between the sections formed by the doors and at one foot from the lower edge of the bin, is placed a punched plate, on which is laid two layers of cocoanut matting, and battened to the woodwork of the bin. This punched plate is supported on cleats nailed to the woodwork of the bin. The bins are arranged so that the overflow water from bins Nos. 1 to 8 flows into either Nos. 9 or 10 bins (which are 4 ft. lower), where further settlement of the fine lead takes place. The clear overflow water from either Nos. 9 or 10 bins gravitates into the mill sumps.

The lead concentrate, comprising jig and table product, drains in the bins to approximately 4 % moisture in three days, when it is ready to be trucked to the smelter.

In addition, a concrete floor 214 ft. x 50 ft., capable of storing 10,000 tons of jig and Wilfley concentrate, is provided.

Zinc Tailing.—A row of ten bins, with a total holding capacity of 2000 tons, and similar in design to those used for lead storage, is provided. The overflow from these bins flows to Dorr thickeners at the slime flotation plant. The clear water is returned to the mill sumps. The zinc tailing is drained from 16 to 24 hours in the bins, and then railed to the treatment plant of the Amalgamated Zinc (De Bavay's) Ltd.

Quartz Tailing.—This tailing, which is made from the fifth row of tables, is elevated into one of three steel vats, 16 ft. 6 in. diam. by 20 ft. deep, fitted with an overflow launder. The dirty overflow discharges to the V settlers. These vats are provided with filter bottoms, and are constructed as follows:—A number of parallel bearers, 4 in. x 3 in., on edge, and spaced 15 in. apart, are placed on the bottom of the vat. The underside of these bearers has a number of V notches cut in them to allow of draining, above which, and at right angles to them, are nailed a number of 2 in. x 1 in. wooden battens, 1 in. apart. Over these battens are placed two layers of cocoanut matting. Wooden battens, 2 in. x 1 in., at right angles to the battens below, and 3 in. apart, are nailed to the ones below; this keeps the matting in position, and forms a shovelling bottom to the vat.

The drained quartz tailing is discharged through a central hole 12 in. diam. on to an 18-in. conveyor. This belt discharges on to a main conveyor belt with 500-ft. centres, running at right angles, and delivers the quartz tail to the open cut, whence it is drawn for stope-filling underground.

Slime.—Prior to July, 1916, all the slime overflow from the mill ran into a series of settling pits.

Twenty-two pits, 24 ft. long, 13 ft. wide, by 4 ft. 6 in. deep at the back and 7 ft. deep at the front, fitted with the usual baffle overflow and cast-iron door, were provided.

In these pits the thin slime pulp was settled. The more or less clear overflow was returned to the mill sumps, while the thickened pulp was elevated to a storage dam. Ordinarily the pits are out of use when the slime is going to the flotation plant.

Mill Water Circulation.—All clear overflow water from bins, vats, thickeners, &c., flows to four steel tanks, 10 ft. deep by 20 ft. diam., fitted with overflows to the mill storage dam. These tanks connect to one common main, which connects to a duplicate set of Sulzer centrifugal pumps. Each set consists of one 7-in. of 40,000 gal. capacity and one 12-in. of 90,000 gal. per hour.

The centrifugal pumps elevate the water to two 20,000-gal. service tanks, which supply the mill.

The Sulzer centrifugal pumps are direct-coupled to the motors, and have given marked satisfaction. The orginal impellers and shafts are still in use.

POWER AND TRANSMISSION.

The coarse-crushing, jigging, and regrinding sections are driven by a 600-b.h.p. Belliss and Morcom high-speed engine, jointly with a 600-kw. synchronous motor.

The power is transmitted by a cotton rope-drive from the engine-drum to the main line of shafting.

Gates breakers and roll-feeders are belt-driven, and the rolls are gear-driven from the main line of shafting.

A second rope-drive extends from the main mill-shafting to the grinding pan countershaft, from which jigs, elevators, and screens are belt-driven through the jig countershaft. In the table section the tables and elevators are motor-driven.

Two 35-b.h.p. motors are required for the tables.
Two 35-b.h.p. ,, ,, ,, elevator.
One 8-b.h.p. ,, ,, ,, ,,

Mill Housing.—The Gates breakers, crushed crude-ore bins, rolls, jigs, and grinding pan sections are housed in a building 204 ft. long by 132 ft. wide, constructed of oregon and covered with galvanized iron where covering is required.

The tables are housed in a separate building of similar construction, 191 ft. long by 160 ft. wide. The floors and foundations of the mill are of concrete.

Since the above system ceased work in May, 1919, the crusher and jigging end was destroyed by fire, and it is now being rebuilt under new design.

When the De Bavay contract terminates a fine-grinding plant and zinc flotation section will be installed, and when these alterations are completed a further description will be given.

PART II.

THE SLIME FLOTATION PLANT.

FROM the inception of the first gravity concentrating mill on the mine in 1894 to November, 1916, 450,000 tons of slime were produced and stocked in dams, assaying—

10.7 % Pb, 5.9 oz. Ag, 14.2 % Zn.

In addition, the present concentrating mill produced up to 1000 tons of slime per week, depending upon the tonnage hauled from underground.

The average grading analyses of both recent dump and current slime are as follows :—

—	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
60 ..	.211	3.5	2.0	.7	3.6	.7	.4	1.0
100 ..	.127	5.1	2.0	1.3	5.6	1.0	.9	2.1
150 ..	.084	4.5	2.6	1.4	6.6	1.1	.9	2.2
200 ..	.063	1.0	2.4	1.4	8.0	.2	.2	.6
−200 ..	.063	85.9	11.5	7.9	14.6	97.0	97.6	94.1
Average	..	100.0 ..	10.2	7.0	13.3	100.0	100.0	100.0

The following is the analysis of the average slime:—

	%
Silica (SiO_2)	36.6
Lead (Pb)	9.6
Arsenic (As)	.2
Antimony (Sb)	.1
Cadmium (Cd)	—
Copper (Cu)	.2
Ferrous oxide (FeO)	6.3
Alumina (Al_2O_3)	3.7
Manganous oxide (MnO)	4.9
Lime (CaO)	8.9
Zinc (Zn)	12.6
Sulphur (S)	9.0
Carbon dioxide (CO_2)	6.9
Fluorine (F)	1.0
	100.0
Silver	7 oz. per ton.

The main minerals present are:—Galena, blende, calcite, pyrites, and chalcopyrite.

This material, when treated experimentally by the earlier flotation methods, produced a collective float concentrate, assaying—

% Pb.	Oz. Ag.	% Zn
26.2	19.0	34.8

and a purchaser was not found for the concentrate on account of its high zinc content.

PATENTS.

In 1913, J. F. Lyster and T. M. Owen each independently applied for and obtained patents for a preferential flotation process.

The Lyster process depended upon the addition of a frothing agent, such as eucalyptus, to a circuit containing a large proportion of salts in solution, such as is usually found in mine waters at Broken Hill.

The Owen process depended upon the addition of a very small amount of a frothing agent, such as eucalyptus, to the circuit, and the subsequent violent aeration of the pulp.

Either process working on current production slime (*i.e.*, slime that has not become dry) will preferentially float the galena from the blende and gangue minerals, the blende being subsequently recovered by one of the known flotation processes.

EXPERIMENTAL.

During 1913, Owen, whose process was in the laboratory stage, brought it under the notice of the South mine management, and the officials of the South mine proceeded to experiment with and develop the process.

The first experimental apparatus consisted of an ordinary two-litre glass bell jar, inverted, the neck being closed with a single hole rubber stopper, fitted with a glass tube, over which slipped a piece of rubber tube with clip. Through this hole, when the clip was opened, air was drawn by a rapidly revolving impeller, set close to the bottom of the jar. The apparatus so arranged would treat a charge of slime weighing 500 grm.

The tests with this apparatus proved that the galena could be separated from the blende and gangue.

In practice the froth was awkward to remove with the above apparatus.

A second experimental vessel was then constructed of brass, with a glass sight-window, and operated with a 10-lb. sample of slime.

Fig. 14 shows the apparatus in which all of the early tests were conducted.

The following is a descripton of the operation of testing the ore with the above apparatus :—

Ten lb. of slime is taken and added to the running machine, which already contains approximately 1 gal. of cold water; the frothing agent, usually eucalyptus oil, equivalent to 0.1 lb. per ton, is added from a burette; the pulp and oil are then churned together by the impeller of the apparatus for half a minute, more water is added, and the air inlet opened; this causes a heavy froth carrying the galena to separate and overflow into a launder at the top of the apparatus, thence to a settling tin or box.

When the bulk of the galena has frothed off, the finest portion of the blende commences to rise, changing the colour from the blue of galena to the brown of blende. This is the main indication when the bulk of the galena has floated off. With practice the operator becomes expert in noting the change in colour, and so obtains clean products.

When the bulk of the galena has frothed off, the air inlet is closed, eucalyptus (equivalent to 0.5 lb. per ton) and the requisite quantity of sulphuric acid cautiously added, the air inlet is again opened, and the blende frothed off. The residues are then drained off at the bottom of the vessel.

When running a number of experiments it is much more convenient to calculate the weight of residue from the usual pulp formula, which depend upon the specific gravity of residue and water.

With this type of apparatus all of the products can be readily collected and sampled.

The following is a typical test taken from amongst a batch of 90 separate tests carried out with the apparatus on South mine current slime :—

Weight of sample taken, 10 lb.

Lead flotation { Water, mill circuit.
Temperature, 20° to 24° C.
Oil, eucalyptus, 0.1 lb. per ton of slime.

Zinc flotation { Temperature, 20° to 24° C.
Oil, eucalyptus, 0.5 lb. per ton of slime.
Mono-H_2SO_4. 100 lb. per ton of slime.

	% weight.	Assay.			Proportion.		
		% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
Lead concentrate ..	12.5	71.0	46.0	7.5	86.2	84.5	7.7
Zinc concentrate ..	19.1	4.5	3.5	50.7	8.3	9.8	80.0
Zinc middling ..	2.2	6.5	3.0	31.5	1.0	0.9	5.7
Final residue ..	66.2	0.7	0.5	1.2	4.5	4.8	6.6
	100.0	10.3	6.8	12.1	100.0	100.0	100.0

In the early development of the Owen process, tests were made on the current slime material, varying the conditions so as to meet all possible conditions likely to occur in the working of a large plant.

From the results of these laboratory tests a unit was constructed to treat one ton of material in one charge. This apparatus was cylindrical, 8 ft. deep, and 3 ft. 6 in. diam.

This unit was at first fitted with two 4-in. centrifugal pumps for agitating and aerating the pulp ; subsequently an auxiliary air supply was added, in which the plain jet injector and porous plates ideas were tried out.

Although the pneumatic type of flotation apparatus has been mostly developed and brought to its high state of perfection by American metallurgists, in fairness to the experimental metallurgists, Messrs. W. J. M'Bride (of the Broken Hill South) and W. J. Rose (of Amalgamated Zinc Co.), whose work was interrupted by the war, we place on record that they were trying out the porous bottom idea as early as June, 1913.

The following are the typical results obtained by the one-ton unit :—

Galena Float from One-Ton Unit.

TABLE IV.

Feed.	Means of aeration.	Assay.											
		Feed.			Concentrate.			Residue.			Recovery.		
		% Pb	OzAg	% Zn	% Pb	OzAg	% Zn	% Pb	OzAg	% Zn	% Pb	% Ag	% Zn
Current Mill Slime.	2 4-in. pumps	11.0	7.5	13.6	65.5	41.4	10.1	3.5	3.5	14.2	72.0	58.3	10.6
	Pumps working with porous plate ..	13.8	—	16.0	53.6	42.9	10.8	2.0	—	15.3	88.8	—	10.5
	Pumps with air-jet injector	13.0	9.8	14.6	61.3	38.7	9.4	3.5	2.3	15.4	77.6	81.3	8.6

After completing the tests on the one-ton unit, using pumps, the machine was altered to an underdriven agitating unit.

The agitating impeller was made 2 ft. in diam., with four blades set at right angles with a pitch of 45° (Mineral Separation type).

Development of Impeller.—The first impeller fitted to the machine was the ordinary Mineral Separation impeller, 2 ft. diam., with the blades cast with a pitch of 45°. The impeller was driven at a spindle speed of 300 r.p.m.

The dimensions of the unit were 8 ft. deep, 3 ft. 6 in. diam. The object of these tests was to try and develop an impeller that would draw in sufficient air from the atmosphere to thoroughly aerate the pulp, similar in action to the small laboratory machine.

With the above impeller it was found that with a head of 3 ft. 9 in. of water, air-suction failed.

A 12-in. diam. steel plate was rivetted on to the top of the impeller, and again tried, when it was found that suction failed with 5 ft. head of water.

The impeller was taken out, and the plate on top increased to 18 in. diam. With this impeller driven at 400 r.p.m., and with an 8-ft. head of water, the air suction was fair.

Having demonstrated that the agitating impeller could be made to draw all the air required for the process, the design with four blades, with a pitch of 45°, being a little awkward to make, a cast-iron impeller 18-in diam. was made with eight 1-in. vertical lugs cast to the underside of a disc. This type of impeller proved to be quite satisfactory, and to draw more air per minute, and against a greater head of water, than the type with 45° blades.

This type of impeller was the result of experiment and design of both the chief engineer and chief metallurgist, who were seized of the great importance of thoroughly incorporating air with the pulp, and also to invest the machine with the property of drawing its own air.

This was the first working machine constructed in Broken Hill of the sub-aeration type.

Although credit has been given to the Sulphide Corporation for having introduced the sub-aeration machine, and it has frequently been referred to in letterpress as the Hebbard–Harvey sub-aeration type, the officers of the Sulphide Corporation first saw it in the South mine experimental unit on the 23rd July, 1913, and had treated in this unit a parcel of Central mine Mineral Separation plant slime and sand feed, afterward incorporating this idea in their own plant. The Sulphide Corporation's first experimental unit of the above type was christened by them "the M'Bride plant."

TABLE V.

Table Giving Particulars and Results from Underdriven Impeller in 8 ft. x 3 ft. 6 in. Vessel—Galena Float.

Type of Impellers.	Diam. of Impeller	R.P.M. of Spindle.	Condition of Aeration.	Assays.										
				Feed.			Concentrates.			Residue.			Proportion.	
				% Pb.	Oz. Ag.	% Zn.	% Pb.	Oz. Ag.	% Zn.	% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.
M.S. 45°	in. 24	300	Poor ; failed at 3 ft. 9 in. head											
M.S. 45°, with 12-in. plate	24	300	Poor ; failed at 5-ft. head											
M.S. 45°, with 12-in. plate	24	400	Poor ; failed at 7 ft. 6 in. head											
M.S. 45°, with 18-in. plate	24	400	Good at 8 ft. ..	10.3 10.6	6.9 7.0	13.9 13.6	54.5 58.0	36.0 40.0	16.3 12.0	1.4 2.0	1.3 1.8	14.0 13.9	88.7 83.9	84.3 77.9
Disc Imp., 8 1-in. lugs above and below ..	24	400	Good	11.0 11.0	7.5 7.2	14.0 13.6	64.2 59.6	41.2 40.7	9.0 10.2	2.2 4.0	1.7 3.0	14.0 13.6	82.8 68.2	80.8 63.0
Disc Imp., 8 1-in. lugs below	12	800	Good	9.6 10.2	6.5 6.8	14.6 13.9	60.0 67.0	42.7 42.0	10.0 7.6	2.5 2.0	2.0 2.2	16.0 15.1	77.2 82.8	72.8 71.0
Disc Imp., 8 1-in. lugs below	12	1000	Good	10.6	7.2	12.7	56.0	41.4	12.0	2.2	1.2	15.8	82.6	85.9

Small Experimental Continuous Unit.—A six-vessel continuous plant, capable of handling one ton per hour, was erected. At the beginning very poor results were obtained, and after a good deal of adjustment the results were improved, but they were not as good as the results from the batch unit. The following statement shows the results of work from this apparatus:—

Small Continuous Experimental Unit—Galena Float.

TABLE VI.

No.	FEED.		CONCENTRATE.		RESIDUE.		RECOVERY.
	% Pb.	% Zn.	% Pb.	% Zn.	% Pb.	% Zn.	% Pb.
1	12.5	13.5	51.0	15.7	7.5	14.0	46.8
2	12.8	13.7	48.0	13.7	5.0	13.2	68.0
3	12.0	13.6	39.0	14.3	5.4	13.4	63.8
4	12.1	14.0	60.0	10.4	4.0	13.7	71.8
5	10.7	15.0	59.0	9.2	5.2	13.5	56.3
6	11.2	14.1	52.0	12.0	7.0	14.5	43.3
7	12.6	13.6	52.5	12.0	6.1	15.8	58.4
8	11.7	13.8	54.0	13.1	4.5	14.0	67.2
9	10.6	13.8	52.0	12.0	3.3	14.0	73.4

Batch Unit.—Further tests were then made with the 8 ft. x 3 ft. 6 in. unit to check the previous tests.

The following results were obtained:—

Batch Unit 8 ft. x 3 ft. 6 in. Galena Float.

TABLE VII.

No.	FEED.			CONCENTRATE.			RESIDUE.			RECOVERY.	
	% Pb.	Oz.Ag.	% Zn.	% Pb.	Oz. Ag	% Zn.	% Pb.	Oz.Ag	% Zn.	% Pb.	% Ag.
1	11.7	7.6	12.6	61.0	43.0	7.5	1.1	1.6	11.5	92.2	82.1
2	12.0	7.6	12.5	63.0	41.3	7.1	1.6	1.9	10.8	88.9	78.7
3	11.5	7.2	12.5	56.0	43.6	9.6	2.9	2.2	12.7	78.9	73.2
4	10.6	6.8	14.1	52.5	41.0	12.0	1.4	1.3	14.5	89.1	83.5
5	10.7	7.0	14.6	60.0	45.6	9.0	2.0	1.7	15.5	84.2	78.7
6	10.3	6.6	14.7	58.0	42.0	10.5	2.4	1.6	15.0	80.0	78.6

DUMP OR ACCUMULATED SLIME.

The Company's accumulated dumps, amounting to 450,000 tons, were sampled, and average parcels tested out by the new process.

These tests showed that, as long as the slime sample came fresh from the interior of the dump, a fair recovery of the lead and silver could be expected by the process, but directly the slime became air-dried, or weathered, the preferential float for lead was partially inhibited; this is clearly shown in the following two tests.

The following are typical results obtained experimentally by the process working on the dump slime :—

Sample of Slime from Interior of Dump, carrying 25 % *moisture, floated with* 0.1 *lb. eucalyptus.*

% weight.	Assay.			Recovery.		
	% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
7.1	46.0	33.3	20.5	35.0	37.3	11.6
7.1	36.4	27.4	27.6	27.8	30.7	15.6
5.0	27.0	19.6	30.1	14.6	15.5	12.0
80.8	2.6*	1.3	9.4	22.6	16.5	60.8
100.0	9.3	6.3	12.5	100.0	100.0	100.0

* 0.5 % Pb oxidized.

Sample of Slime from Interior of Dump, air-dried and treated with 0.1 *lb. eucalyptus.*

% weight.	Assay.			Recovery.		
	% Pb.	Oz. Ag.	% Zn.	% Pb.	Oz. Ag.	% Zn.
4.0	32.7	—	14.7	13.7	—	4.6
96.0	8.6*	—	12.8	86.3	—	95.4
100.0	9.6	—	12.9	100.0	—	100.0

* 1.5 % Pb oxidized.

SUMMARY OF LABORATORY AND ONE-TON UNIT EXPERIMENTS.

1. The experiments indicated that, on a commercial scale, the process would give a preferential galena float containing the bulk of the lead and silver on the fresh current slime from the concentrating mill

2. With slime fresh from the dump a fair preferential galena float could be obtained.

3. With slime that had become air-dried and partially oxidized, the preferential galena float became very much retarded, and at times entirely inhibited.

4. Coarse galena (*i.e.*, plus 100 mesh, .127 mm.) would not preferentially float from the blende and gangue.

5. Only very small quantities of a frothing agent were required.

6. With current slime a concentrate of 60 % grade with a recovery of 80 % of the lead could reasonably be expected.

As a result of the experimental tests and development of the process, the management decided to erect a plant to treat half of the current mill slime—

(*a*) For preferential flotation of galena.

(*b*) For subsequent flotation of the blende.

Provision was made in the general lay-out to enlarge the plant so that it would have a capacity for the treatment of the whole of the current slime produced in the gravity mill—*i.e.*, approximately 1100 tons per week, and, in addition, to treat 1000 tons of dump slime per week. One unit of this plant was completed and put into operation in July, 1916.

THE COMMERCIAL FLOTATION PLANT.

Description of Flotation Cell.—The flotation cell adopted for the plant was worked up from the laboratory vessel and one-ton unit experiments, and is the design of J. C. Cunningham, the company's chief engineer.

The design of the vessels and the aerating impellers is original. Its chief advantage is that the head of pulp and the apparatus for controlling the head are self-controlled in each cell.

Fig. 16 shows the arrangement of the cells, and Fig. 13 shows the general lay-out of the plant.

The Flotation Cell.— The cell consists of a cast-iron vessel 7 ft. deep, 3 ft. 6 in. diam., provided with baffles.

The cells are connected to each other by a 4-in. diam. pipe, through which the pulp flows to the following vessels of the series. The agitation and aeration of the pulp is performed by a disc impeller in each cell.

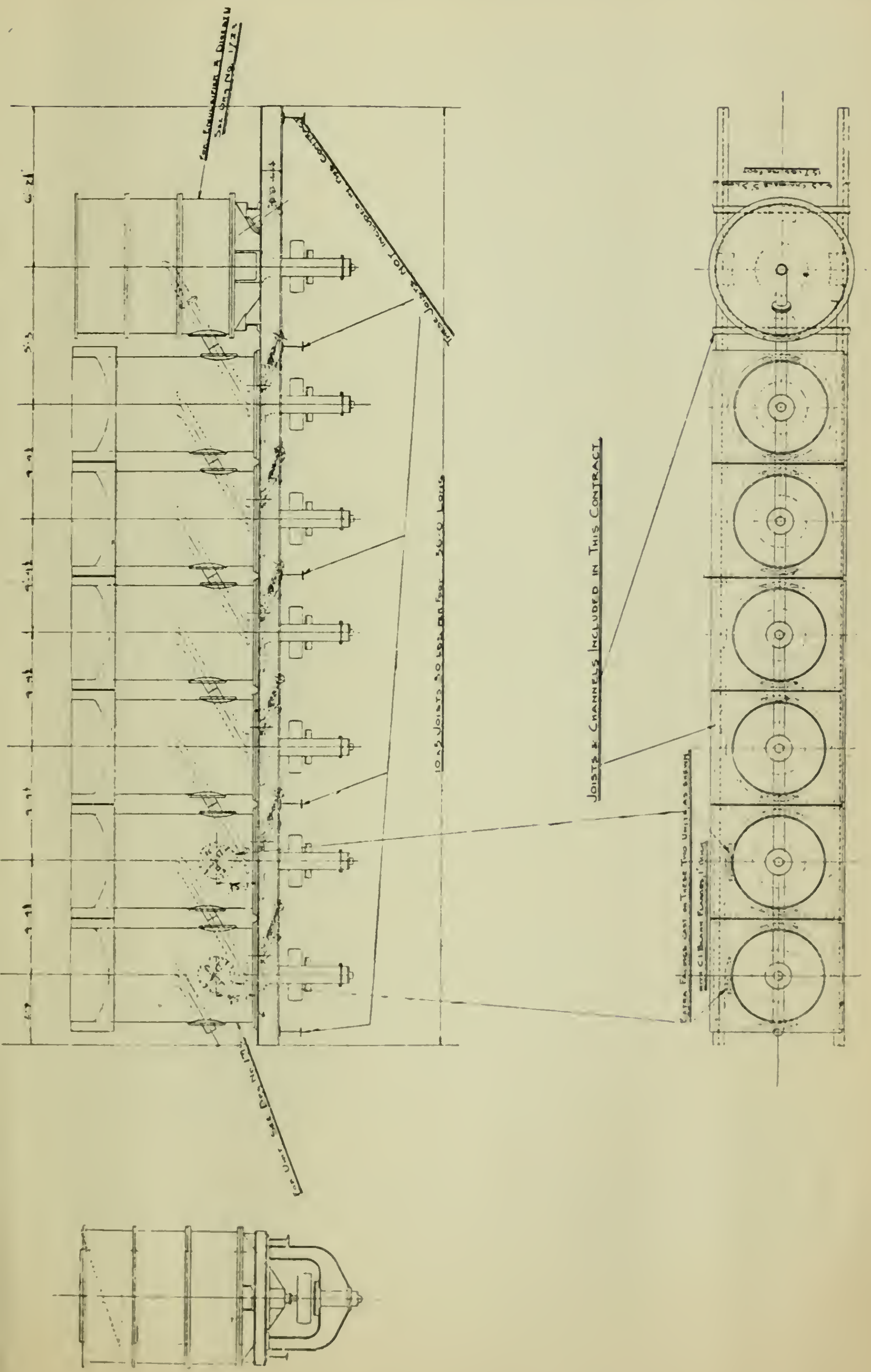


Fig. 16.
General Arrangement Flotation Cells.

The Impeller.—To the writers the impeller is known as a "disc" impeller. The design of it was worked up from the one-ton vessel experiments, wherein it was shown that by attaching a steel plate over the Mineral Separation type of impeller, the head of water through which it would draw air was increased from 3 ft. to 8 ft.

The impeller is made of cast iron, it is 18 in. diam., and is provided on the bottom with eight radial blades, 2⅛ in. deep, and on the top with six volute blades, 1 in. deep, extending to 6 in. radius. The volute blades on the impeller are used for pumping the pulp from the preceding cell. Fig. 18 shows details of the impeller.

Connections from Cell to Cell.—This is with a 4-in. pipe flanged on to each vessel; the 4-in. pipe extends into each vessel, and terminates in each case with a flange.

Control of Pulp in Each Cell.—This is best described by considering two cells. In the second cell the 4-in. connecting pipe extends to the centre of the vessel, and terminates with a 12-in. diam. flange. This flange is parallel to and has a ¼-in. clearance from the top of the impeller. It will be seen that the top side of the revolving impeller now acts as a centrifugal pump, and its function is to draw the pulp from the preceding vessel of the series.

With such an arrangement of pumps in an apparatus, all pumps may not be drawing equal volumes of pulp, due to mechanical defects, wear, etc. To take care of this irregularity, and to give perfect control over each cell in the series, Mr. Cunningham has designed and patented a float control for the system, which is shown in Fig. 17.

The following is a description of the control:—

The 4-in. connecting pipe is extended into the centre of the first vessel, and terminates in a cast-iron flange. A sleeve, 18 in. long and 4½ in. diam., fitted with a flange, is bolted to the cast-iron flange of the connecting pipe; three 2¼-in. distance pieces are placed between these two flanges, so that there is a 2½-in. opening to allow the pulp to flow through.

Fitting loosely in the sleeve is a 4-in. diam. pipe, 8 ft. long; this is made so that it moves freely in the sleeve, past the distance pieces, and forms a seat on the inner edge of the cast-iron flange of the connecting pipe. Attached to this pipe is a float, 18 in. diam. by 2 ft. deep, made either of copper or galvanized iron.

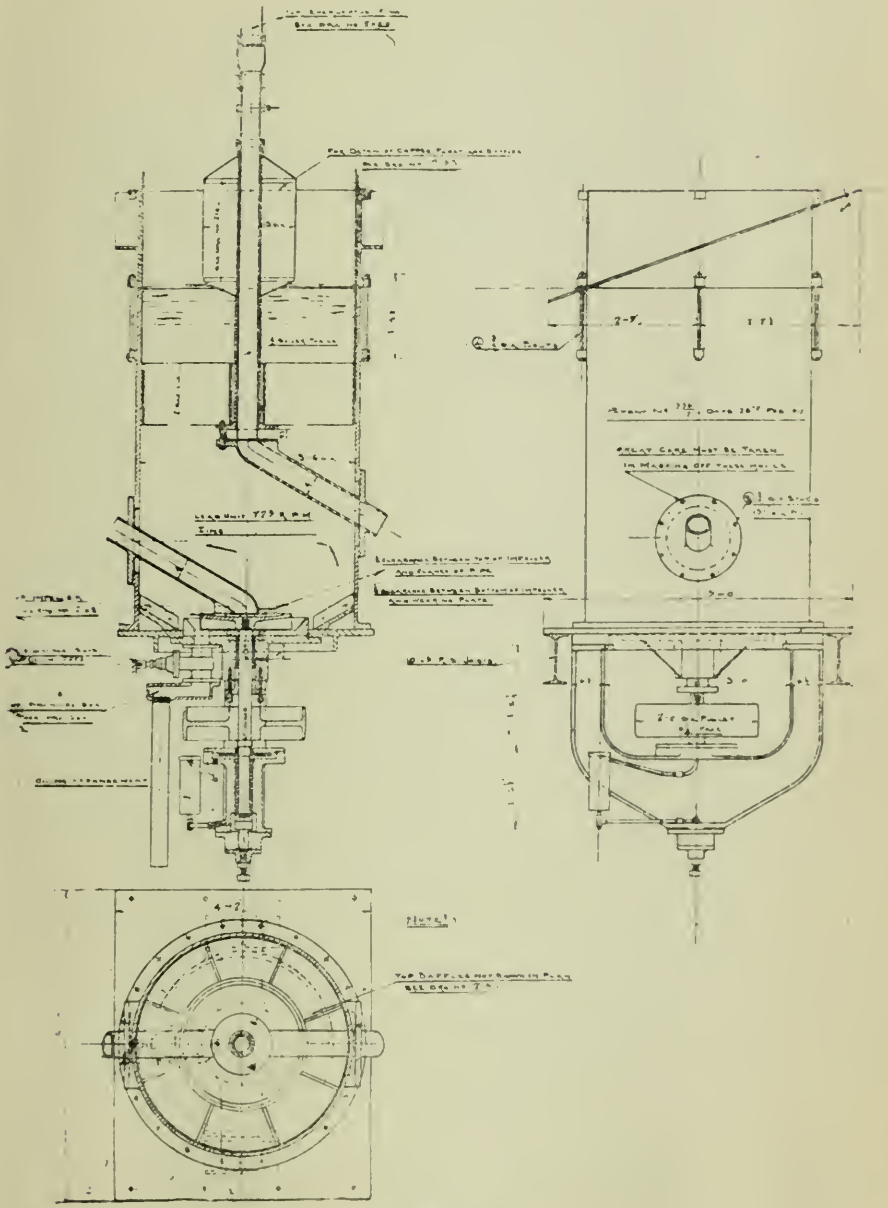


FIG. 17.
FLOTATION CELL FLOAT CONTROL.

The float is adjusted by means of a collar and pin-holes in the 4-in. pipe.

Once the float is adjusted upon the 8-ft. pipe to give the required pulp level in each vessel, any tendency for one impeller to pump faster than the other is taken care of by the pipe, with float attached, either seating past the distance pieces or opening sufficiently to allow the pulp to flow more rapidly.

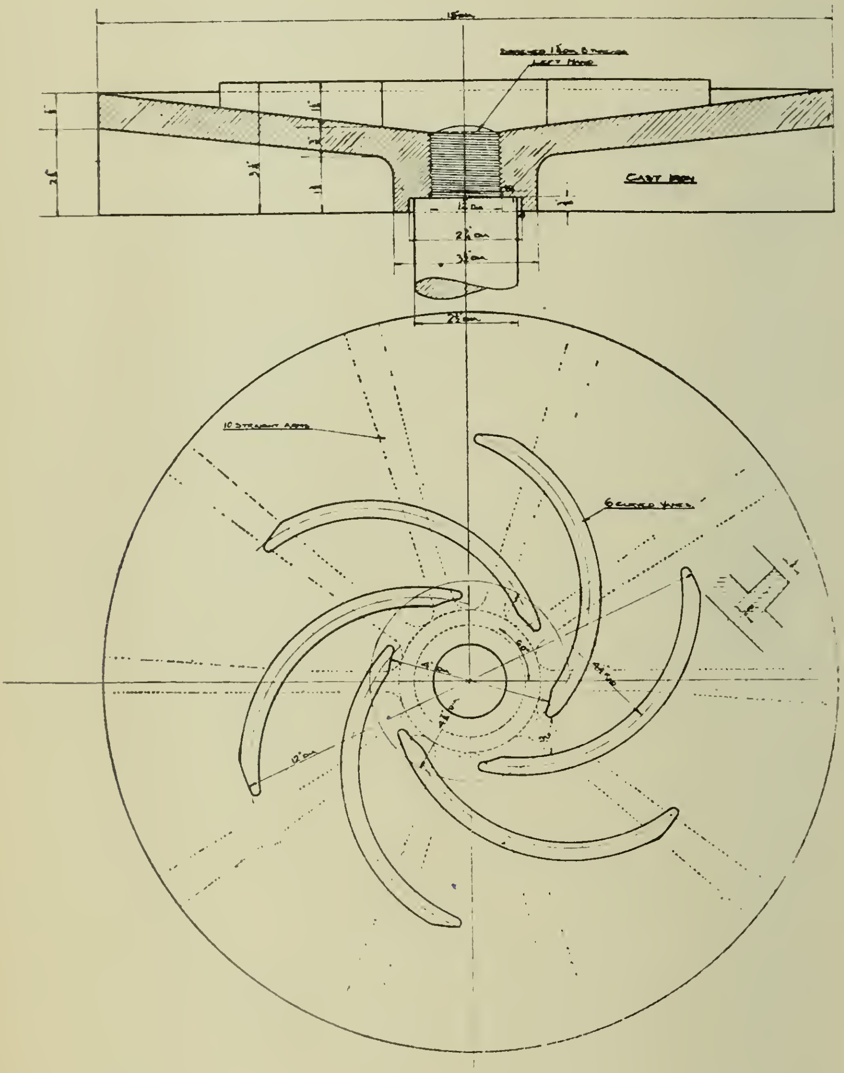


FIG. 18.
IMPELLER.

The whole 4-in. pipe from the impeller to the top of the float is open to the atmosphere, and thus becomes an "air-balanced valve."

In practice, this float control has worked exceptionally well; the variations in pulp level are never greater than 1½ in., and on one setting of floats the plant will operate for weeks.

With this system of control, all of the flotation vessels can be erected on the one floor level, the variations in depth of froth being varied by the control.

In the nine-vessel unit at the South mine the cells are all on the one floor level. The first cell operates with a 15-in. depth of froth, and there is gradual decrease until, at the end or ninth vessel, the depth of froth is 4 in.

Baffles.—The South mine started off with cast-iron baffles extending half-way up the cell, but has finally adopted a wrought-iron spider baffle, 12 in. deep, immersed to 3 ft. 6 in. from the top of the cell.

Aeration of Pulp.—The air necessary for the process is drawn into the pulp at the bottom of the vessel, through two 1-in. pipes, by the suction of the impeller. The pipes are connected to a 1½-in. pipe, which extends to the operating floor, where the quantity of air admitted is controlled by a 1½-in. plug cock.

The two 1-in. pipes are tapped into the bottom of the vessel, and enter a recessed ring, 6 in. diam. by 1 in. x 1 in. Over this recess is fitted a cast-iron wearing plate, provided with six ⅝ in. diam. holes for air admission.

Bottom of Cell.—This is made in two portions, and is shown in Fig. 19. The outer portion is a plain plate, 5 ft. square, with a central opening 2 ft. 0½ in. diam.

A recessed cast-iron plate with a boss bolted to the bottom plate covers the central opening. It is through this boss that the spindle of the impeller passes. The boss is machined out to take the necessary brass bush and cotton packing to form a water-tight gland.

Fitting into the recess, where the two bottom plates are bolted together, is the cast-iron wearing plate referred to under "Aeration of Pulp."

Bridle Mounting the Driving Wheel and Spindle.—Bolted to the bottom of the vessel is a heavy cast-iron bridle, with 3 ft. 6½ in. centres. A boss is cast in the centre of the bridle, and is machined out to take

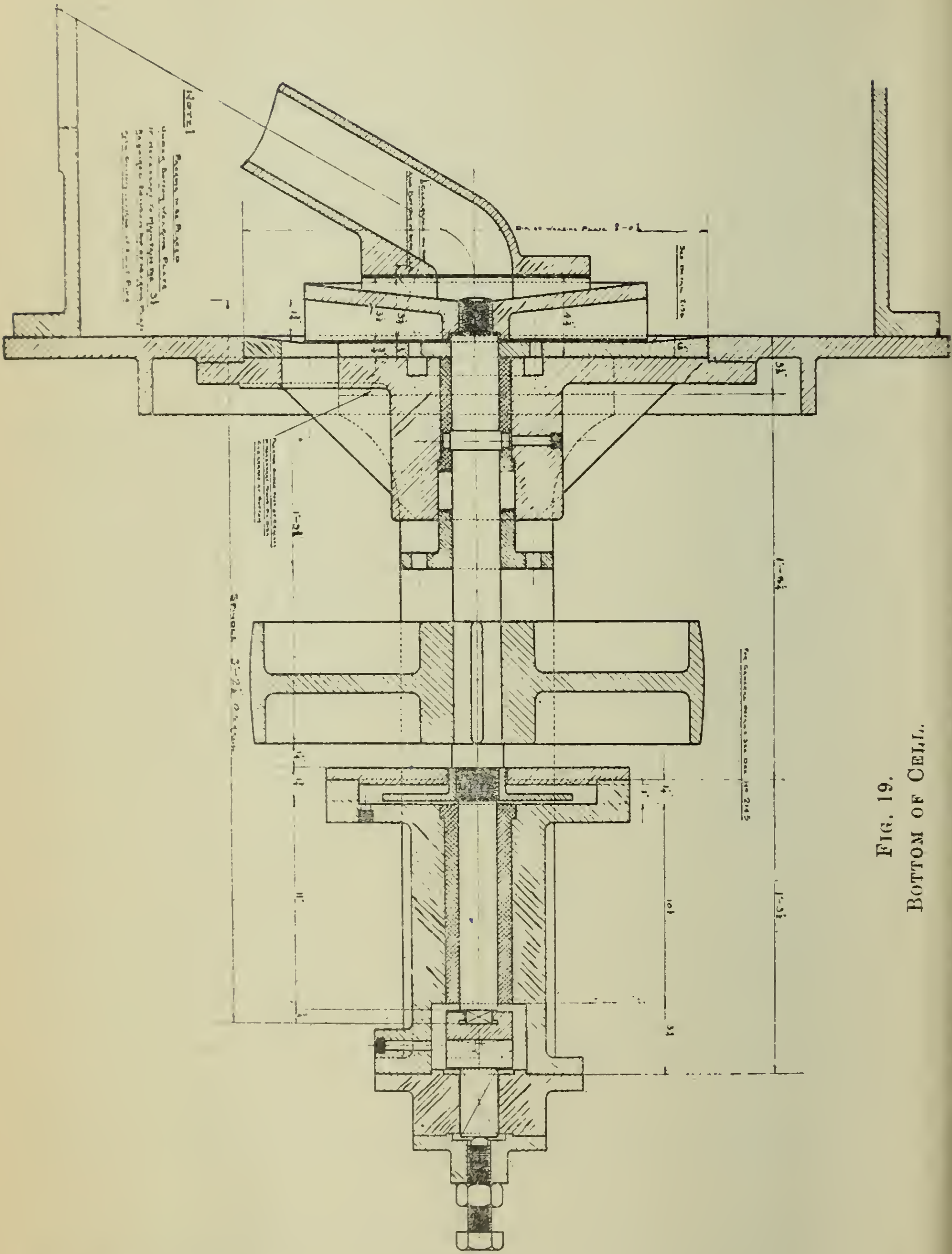


FIG. 19.
BOTTOM OF CELL.

the long white metal bush of the impeller spindle shown in Fig. 19.

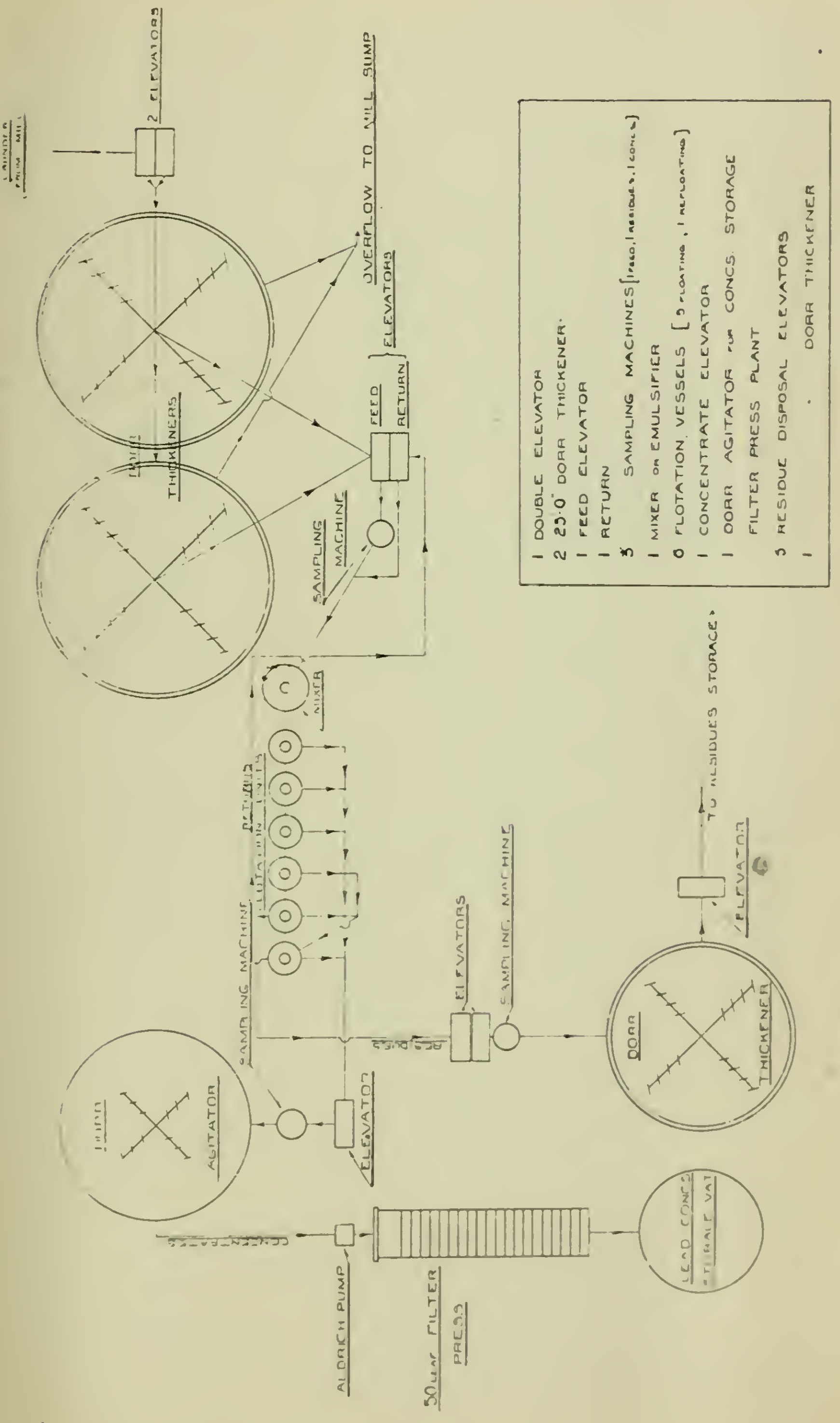


Fig. 20.

1. The Plant as Completed, had the above Flow Sheet.

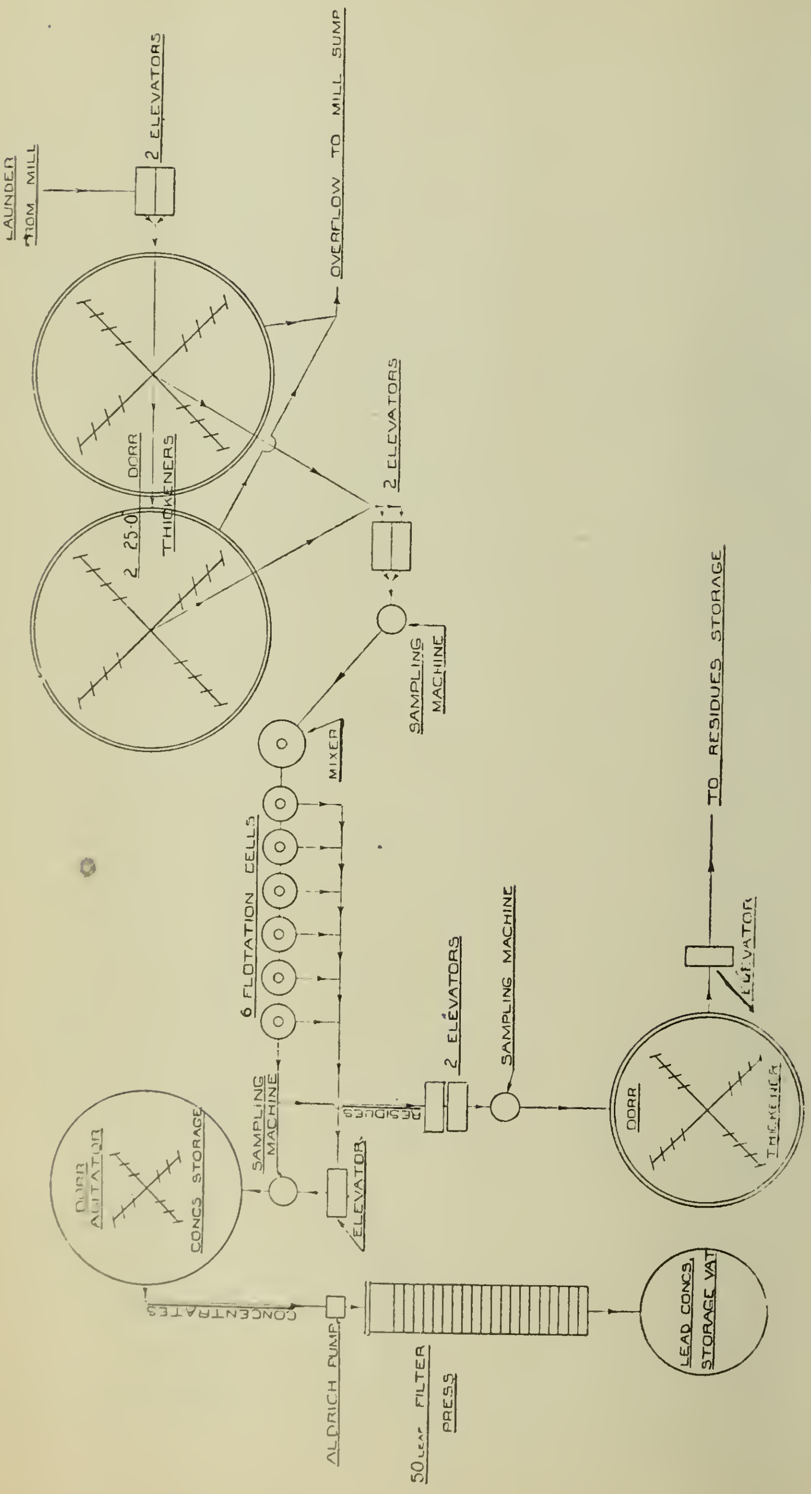


FIG. 21.

2. PLANT REARRANGED WITH NO RETURNS.

The spindle carrying the impeller is 2½ in. diam. and 3 ft. 2 in. long, the impeller being screwed on.

Clearance of Impeller.—This is set approximately ⅛ in. off the wearing plate, and is regulated by means of a heavy set screw and lock-nut at bottom of the footstep bearing.

Footstep Bearing.—The bearing that is used is shown in Fig. 19. The wearing surfaces are hard steel on hard cast-iron.

Oiling of Footstep Bearing and White-Metal Bush.—This is done automatically by a rotating disc, and is shown in Fig. 19. Above the boss carrying the white metal bush is a machined recess, 12½ in. diam. by 1¼ in. deep, fitted with a cover. Screwed on to the impeller spindle is a disc 10 in. diam. and ⅜ in. thick, which rotates with the spindle in the above recess. An outside receiver, which holds approximately ½-gal. of oil, is connected by ¾-in. pipe to the footstep bearing, and with a return pipe from the disc recess.

Oil flows by gravity to the footstep, and is drawn by the centrifugal action of the rotating disc through the oil channels of the white-metal bush into the recess, and from there gravitates to the oil receiver.

COMPLETED FLOTATION UNIT.

The flotation unit completed consisted of six vessels, with a mixer vessel. They were arranged five vessels in series with the mixer, the sixth vessel being used for refloating the lower grade concentrate produced from the fourth and fifth vessel of the series.

With this arrangement the concentrate produced assayed—

63.1 % Pb, 44.3 oz. Ag, 10.1 % Zn.

The smelter contract called for a 60 % grade of lead concentrate. As the flotation concentrate assayed considerably above 60 %, the re-treating system was cut out, and the flotation units re-arranged, with the six vessels in series with the mixer vessel. Figs. 20 and 21 show the arrangement and re-arrangement of flow.

The plant ran from 29th July to 28th October, 1916, as shown in the re-arranged flow-sheet, when it was altered to six vessels only, working in series, the mixer vessel being dispensed with, and the frothing agent added direct to the feed box.

Minor alterations were made from time to time, with the object of increasing the tonnage, until finally the plant was increased to a nine-vessel unit.

The following table gives particulars of tonnages of slime treated, with the various alterations:—

TABLE VIII.

Statement Showing Tonnage Treated, Assay, Recovery, and Kilowatt Hour per Ton Treated.

Date running.	MACHINE.				Tonnage.	ASSAY.			RECOVERY.			K.W. hour per ton treated	Remarks.
	Running hours.	Mixer.	No. of frothing cells.	Spindle speed.		% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.		
July, 1916. to 28 Oct., 1916	1220	1	6	600	Conc. 1073	60.2	43.4	9.4	83.7	87.2	10.6	12.3	Countershaft drive, direct float, blade of impeller 1 in. deep.
					Res. 6439	1.9	1.0	13.1	16.3	12.8	89.4		
					7512	10.2	7.0	12.5	100	100	100		
28 Oct., 1916 to 4 Dec., 1916	690	—	6	600	Conc. 453	57.4	44.4	9.5	78.6	85.5	10.1	8.0	Countershaft drive, direct float, mixer cut out.
					Res. 2667	2.0	1.2	14.5	21.4	14.5	89.9		
					3120	10.6	7.4	13.8	100	100	100		
4 Dec., 1916, to 13 Feb., 1917	1230	—	6	600	Conc. 1062	58.8	41.4	9.8	83.9	88.5	11.5	12.5	Countershaft drive, direct float, mixer cut out, impeller blade 1¼ in. deep.
					Res. 5750	2.7	1.0	14.0	16.1	11.5	88.5		
					6812	10.9	7.2	13.4	100	100	100		
13 Feb., 1917, to 15 May, 1917	1514	—	6	745	Conc. 944	64.3	50.6	7.7	83.7	87.0	8.3	18.2	Countershaft drive, machine speed up, impeller blade deepened to 2 in.
					Res. 5966	1.9	1.2	13.4	16.3	13.0	91.7		
					6910	10.9	7.8	12.6	100	100	100		
15 May, 1917, to 10 June, 1917	518	—	7	745	Conc. 515	66.3	51.4	7.3	73.1	86.0	7.5	16.2	As above.
					Res. 3285	3.5	1.3	14.1	26.9	14.0	92.5		
					3800	11.3	8.1	13.2	100	100	100		
10 June, 1917, to 23 July, 1917	255	—	7	745	Conc. 248	63.8	49.1	7.2	84.1	88.3	6.8	24.0	Direct drive, impeller 2⅛ in., low tonnage.
					Res. 1452	2.5	1.1	13.7	15.9	11.7	93.2		
					1700	11.1	8.1	13.4	100	100	100		
24 June, 1917, to 31 July, 1918	4894	—	9	745	Conc. 4449	61.6	49.2	7.7	79.7	84.4	8.4	32.0	As above.
					Res. 26052	2.6	1.6	14.3	20.3	15.6	91.6		
					30501	11.3	8.5	13.3	100	100	100		

THE PRACTICE OF FLOTATION—CURRENT MILL SLIME FOR LEAD ONLY.

Fig. 22 shows the general flow-sheet of the plant as now arranged. The slime produced in the gravity concentrator gravitates to a nest of six elevators, which distribute the slime to four 25-ft. Dorr thickeners. The central feed pipe of the thickeners is 2 ft. 8 in. diam., and is submerged to a depth of 4 ft. 6 in. The speed of the rakes in the thickener is one revolution in 3½ minutes.

The slime pulp enters the thickener containing 2½ % solids by weight, and the thickeners deliver a thickened pulp containing 55 % solids by weight. The clear overflow water from the thickeners is returned to the mill sumps. Later, all thickeners were provided with an automatic discharge apparatus, whose function was to regulate the density of the thickener discharge. A description is given later.

Water from the flotation circuit is added to the thickened pulp, thinning it down to 45 % solids by weight. In practice it was found that a pulp containing 45 % solids gave the best work.

The frothing agent, which is usually eucalyptus oil, is added to the pulp, after it leaves the thickeners, and is on its way to the elevators, where it is more or less beaten in.

The oiled pulp is elevated by one of a pair of elevators, and the elevator discharge passes over a sampling machine. The sample taken serves for estimating the tonnages treated and the assay value of the feed. A description of this machine is given later. The pulp then flows into the feed box of the flotation unit, from which it passes to the first cell of the series of nine, where it is aerated by air drawn from the atmosphere by the impeller of the flotation cell.

The lead concentrate is frothed over the upper edge of the flotation vessel or cell, and collects into a common launder, while the residue passes to the second cell, where it is further aerated, and a further portion of the galena concentrate frothed over, and so on through the whole series of nine cells. The residue from the ninth vessel flows to an elevator, where it is delivered to one 20 and two 25-ft. diam. Dorr thickeners. The product from the thickeners, containing approximately 50 % of solids and 90 % of the zinc contents of the slime, by weight, flows to an elevator. The elevator discharge delivers to a 4-in. pipe, which runs the slime to a storage dam.

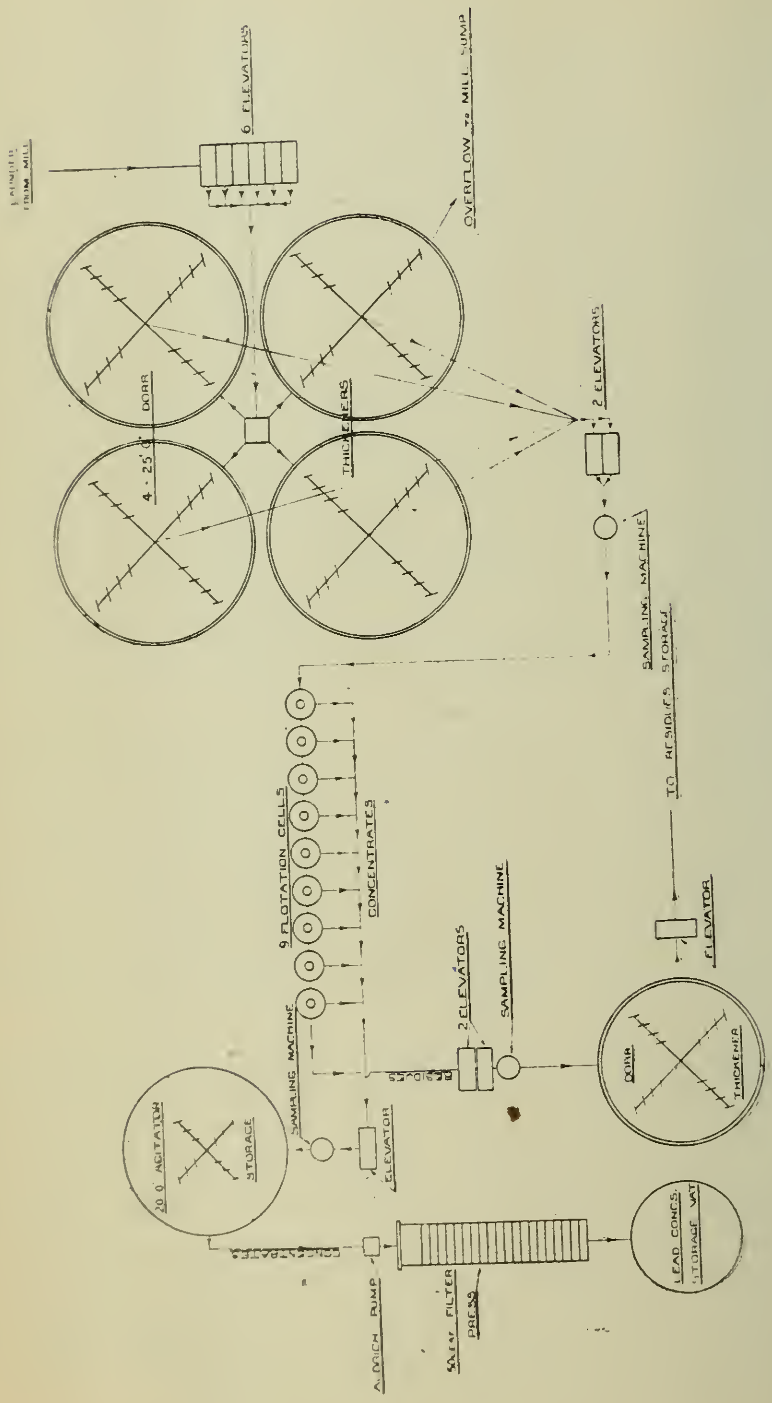


FIG. 22.

GENERAL FLOW SHEET AS NOW ARRANGED.

The clear overflow from the thickeners, as well as clear water drained off the dam, is pumped back to the flotation circuit with 4-in. centrifugal pumps.

Lead Concentrate.—The lead concentrate which is frothed off flows into a common launder, and is elevated. The discharge of the elevator flows over a sampling machine, and then to a Dorr agitator.

The Dorr agitator is 20 ft. diam. and 10 ft. deep. The speed of the rakes in the agitator is 6 r.p.m., and serves to break up the froth. The agitator holds approximately one week's production of flotation concentrate, and, to enable a thickened concentrate pulp to be fed to the filter press, the agitator has three 2-in. pipes with plug cocks tapped in the side. They are 18 in. apart (vertical), so that the clear water can be drawn off.

Filter Pressing.—The lead concentrate, thickened to a ratio of 50 % solids, by weight flows to the suction of an Aldrich 3-throw plunger pump, and is then pumped to one of the two Dehne filter presses.

The presses used are 50-leaf, 3 ft. x 3 ft. x 3 in., and when full of concentrate each press holds nine tons.

No washing of the filter cake is required, the filter pressing being required only for drying the concentrate before railing to the smelter at Port Pirie.

The pressed concentrate leaves the filter containing 7 % to 10 % moisture. The dried cake of lead concentrates is dropped from the press through a grid and hopper on to a conveyor belt, and is subsequently elevated to a storage vat.

The cake of concentrate during transit on the conveyor and on the elevator is broken up so that the bulk of it will go through a $\frac{3}{8}$-in. screen, which is a condition required by the smelters.

Variations in the Physical Conditions of the Feed.—In the ordinary course of treatment the lead concentrate froths over, having a small, compact, heavily-loaded bubble, possessing the usual bright blue lustre of the galena. At times, when ore mined in the oxidized zones of the mine and old tailings used for underground filling contaminate the ore from underground, the froth changes to a dirty grey colour, carrying large quantities of gangue minerals, particularly calcite.

The same dirty grey froth always makes its appearance on the flotation plant when cutting in a section of the gravity concentrator which has been down for repairs, and whilst down for repairs the residue tailings are allowed to become air-dried. South mine practice now is to circulate water through the section which is closed down, so as to keep all parts wet.

When this dirty grey froth contaminates the concentrate in the storage agitator prior to filter pressing, it is impossible to dry the cake below 16 % moisture by the usual method. A 16 % moisture is not acceptable by the smelters. The old practice was to dump the concentrate on the ground and air-dry it.

The retention of water in the cake is due to colloid calcite in the concentrate, and, to overcome this, the lead concentrate in the storage agitator is treated with approximately 30 lb. sulphuric acid per ton of concentrate. The moisture in the concentrate, after filter pressing, is then reduced to under 10 %.

Capacity of Flotation Plants.—The unit described above has had a capacity of nine tons of slime per hour, and is capable of treating a considerable extra tonnage without unduly increasing the tailings loss.

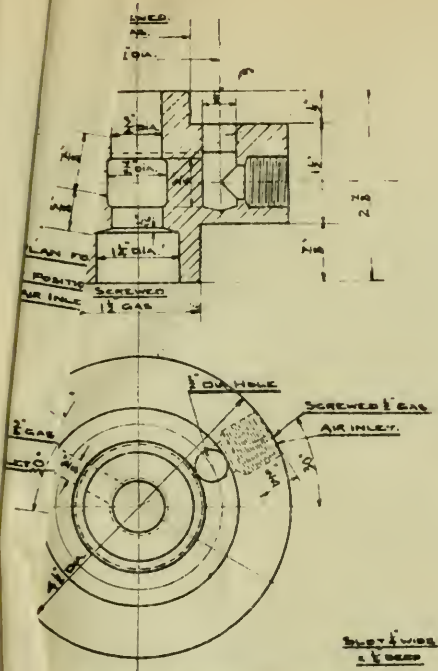
Power.—The plant requires 200 kw., equal to 22.7 kw. hour per ton of ore treated.

Volume of Air Drawn into Each Cell.—The volume of air drawn into each cell by the impeller for aerating the pulp is 2200 cub. ft. per hour. The volume of air admitted to the cell is controlled by a 1½-in. plug cock on the work floor.

Frothing Agent.—Straight crude eucalyptus oil is used for the frothing agent. The consumption of eucalyptus is very low, averaging 0.05 lb. per ton of slime treated.

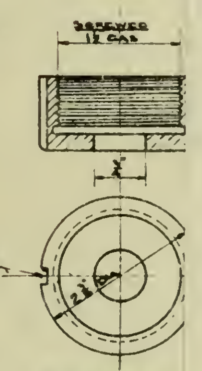
The South mine has tested a large number of wood and coal-tar destructive distillation products for flotation work, with the result that none of them proved as satisfactory as the eucalyptus.

Pulp Sampling Machine.—The machine used for determining the tonnage of slime treated, and at the same time cutting out the sample for assay purposes, is the design of Mr. J. C. Cunningham, and is covered by Patent No. 6648, 1906. Fig. 26 shows the details of the machine. The apparatus consists of two superimposed hollow cones revolving in opposite directions upon a vertical spindle. The cones are so arranged that the uppermost cone receives around its apex, and then uniformly distributes over its surface, the material



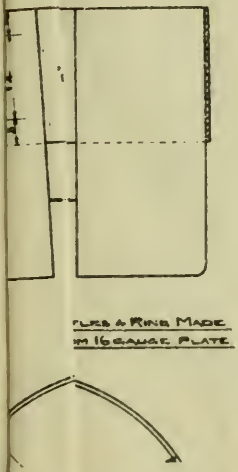
METAL AIR & WATER INLET.

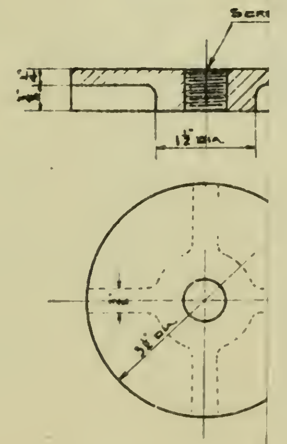
1 OFF.

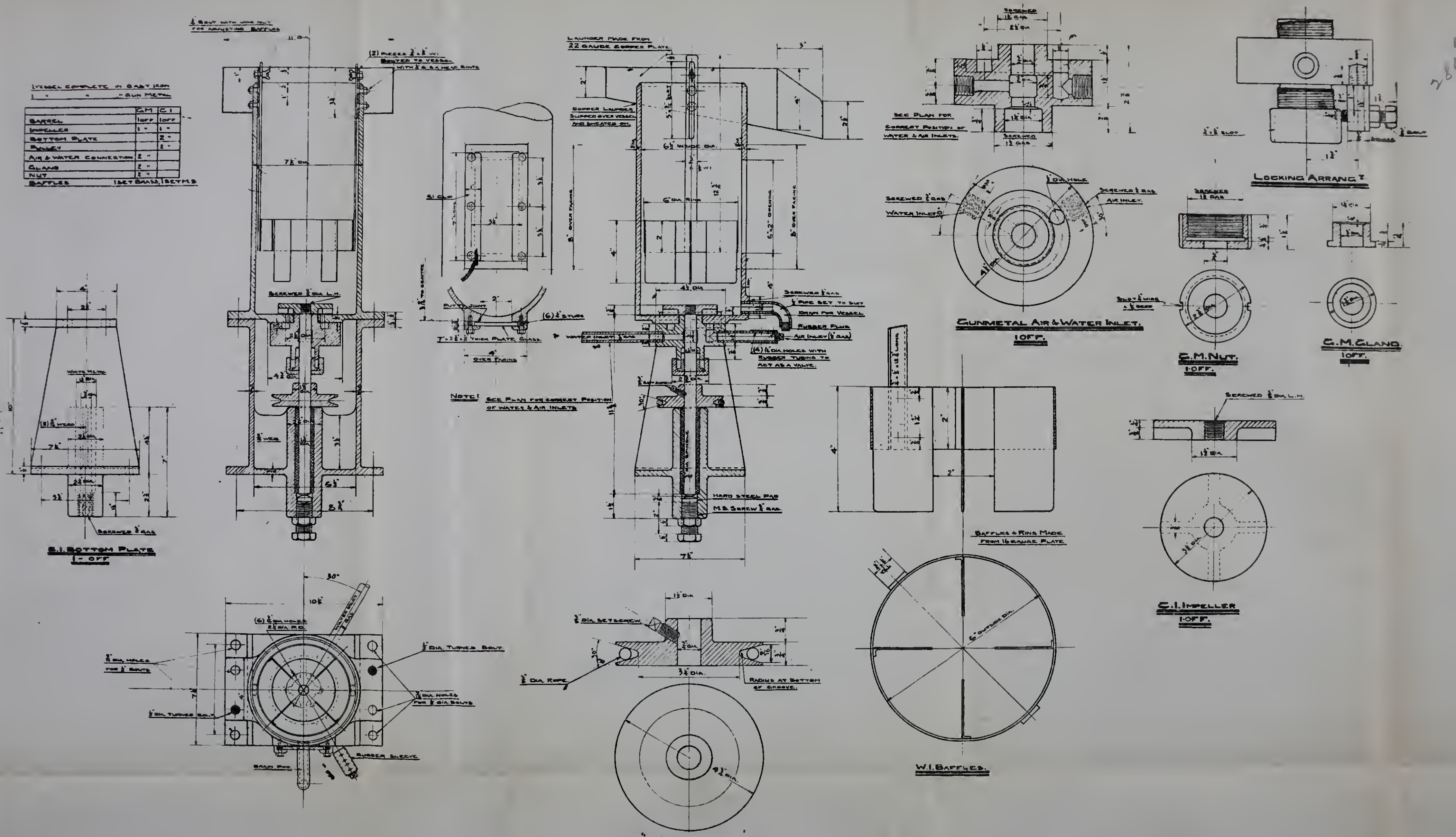


G.M. NUT.

1 OFF.







1 Vessel complete in Cast Iron
1 " " " Gun Metal

	G.M.	C.I.
Barrel	1 off	1 off
Impeller	1 "	1 "
Bottom Plate		2 "
Pulley		2 "
Air & Water Connection	2 "	
Gland	2 "	
Nut	2 "	

Baffles 1 set Brass, 1 set M.S.

LABORATORY FLOTATION UNIT.

EAD--ON CONCENT

TS SEE DRG Nº 2079.

x 20	DEEP
20˙	"
20˙	"
18	"
18˙	"
16˙	"
16˙	"
14˙	"
14˙	"

P. MOTOR 600 R.P.M.

COUPLED TO COUNTER SHA

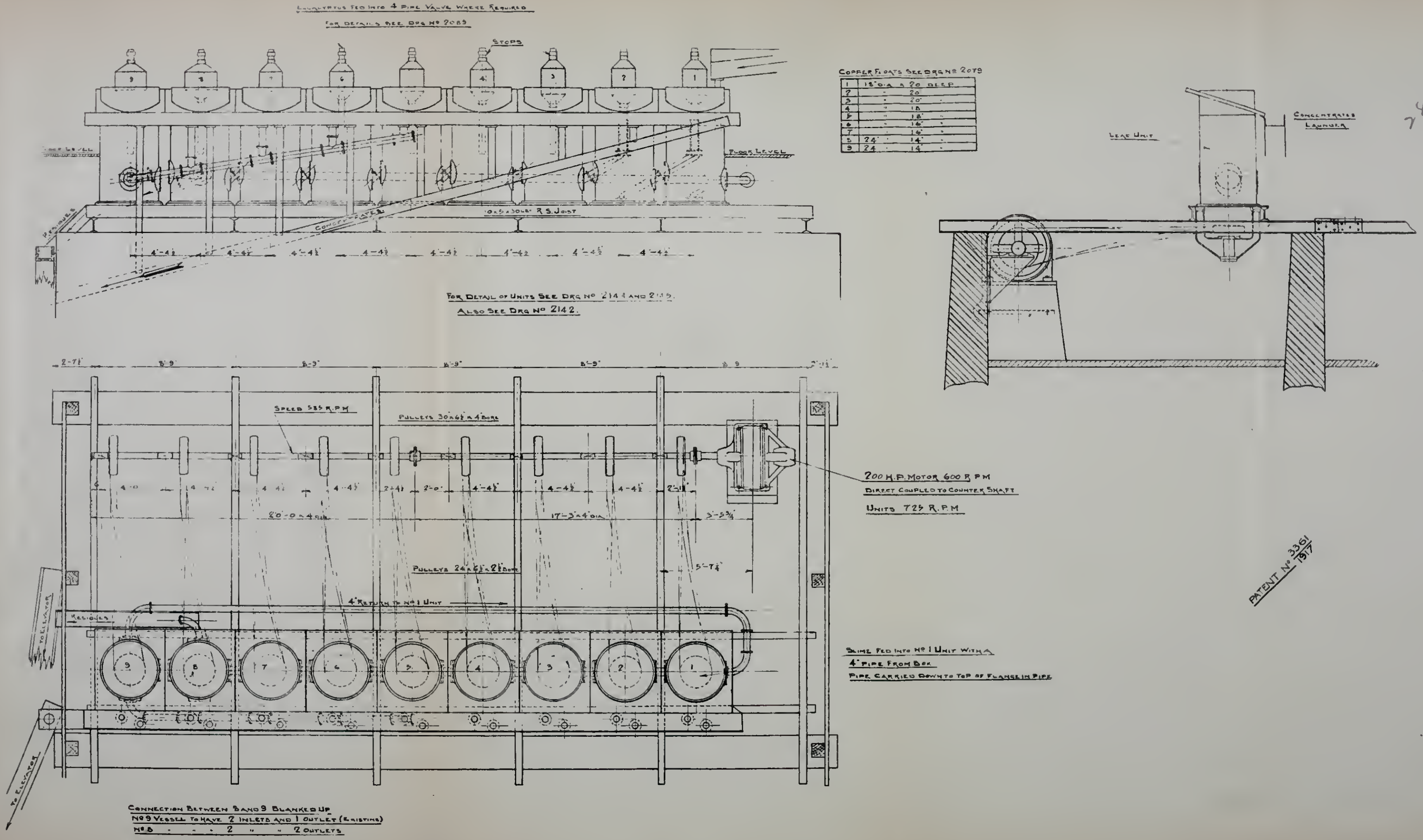
725. R.P.M

NTO Nº 1 UNIT WITH A

OM BOX

RIED DOWN TO TOP OF FLA

2402


Launders Feed into 4 Pipe Valve Where Required
For Details See Drg No 2089
Stops
9
8
7
6
5
4
3
2
1
Floor Level
Floor Level
Residues
Concentrates
10x5x30lb R.S. Joist
4'-4½
For Detail of Units See Drg No 2144 and 2145
Also See Drg No 2142.
Lead Unit
Concentrates Launder
2'-7½
8'-9
Speed 585 R.P.M
Pulleys 30x6½ x 4 Bore
200 H.P. Motor 600 R P M
Direct Coupled to Counter Shaft
Units 725 R.P.M
4'-0
2'-4½
2'-0
2'-5½
80'-0 x 4 dia
17'-3 x 4 dia
3'-5¾
Pulleys 24 x 6½ x 2⅞ Bore
5'-7¾
4" Return to No 1 Unit
Residues
To Elevator
To Elevator
Slime Fed into No 1 Unit With A
4" Pipe From Box
Pipe Carried Down to Top of Flange in Pipe
Connection Between 8 and 9 Blanked Up
No 9 Vessel to Have 2 Inlets and 1 Outlet (Existing)
No 8 " " " 2 " " 2 Outlets
Patent No 3361 1917

Copper Floats See Drg No 2079

1	18" D.A x 20 DEEP
2	" 20
3	" 20" "
4	" 18
5	" 18" "
6	" 16" "
7	" 14" "
8	24" " 14" "
9	24 " 14" "

FLOTATION CELLS ARRANGED FOR RE-TREATMENT.

GHT & READ—ON CON

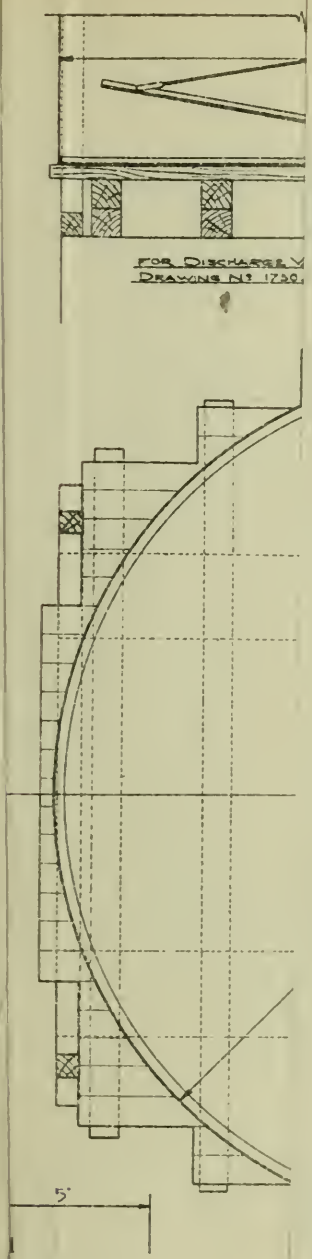
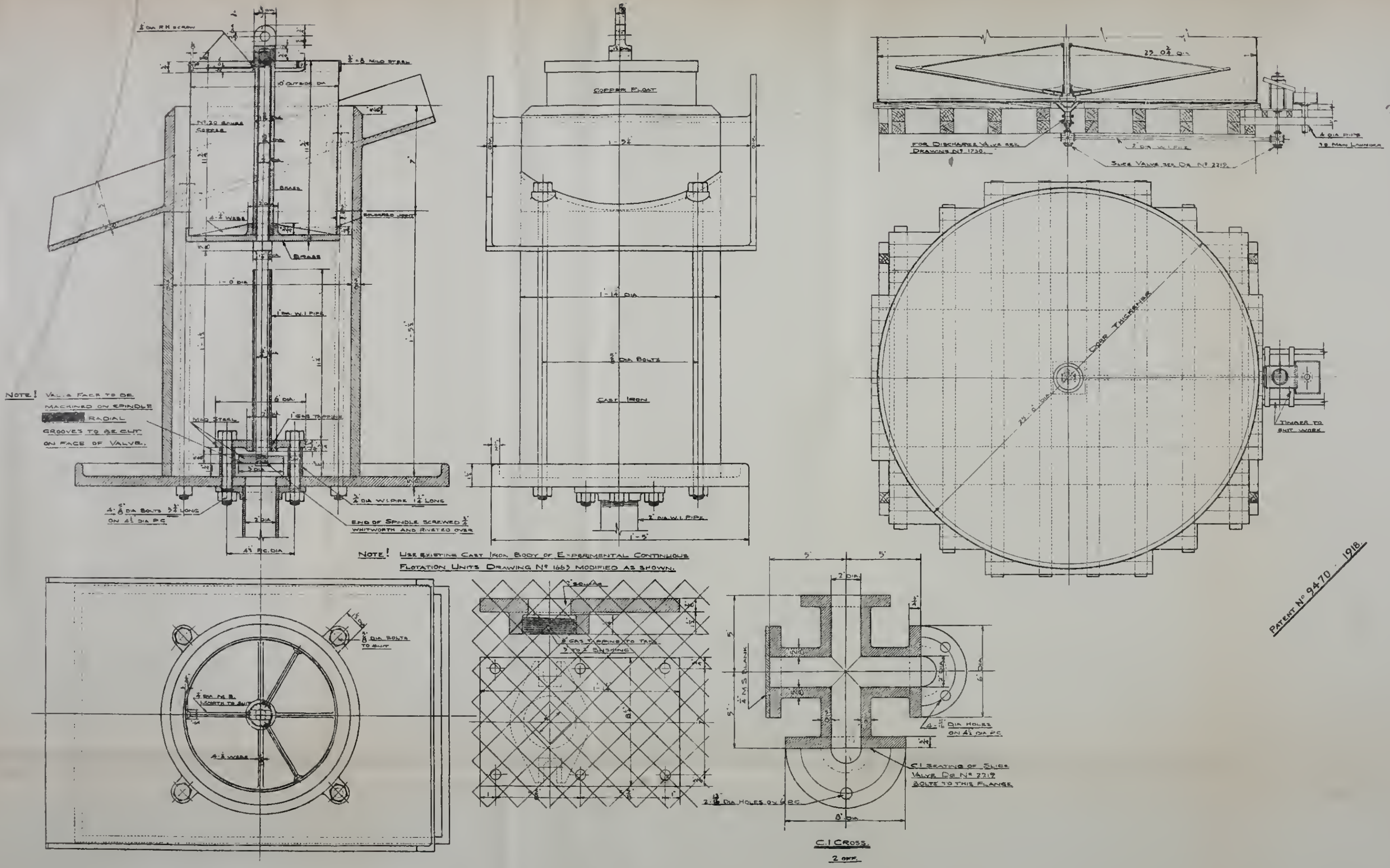
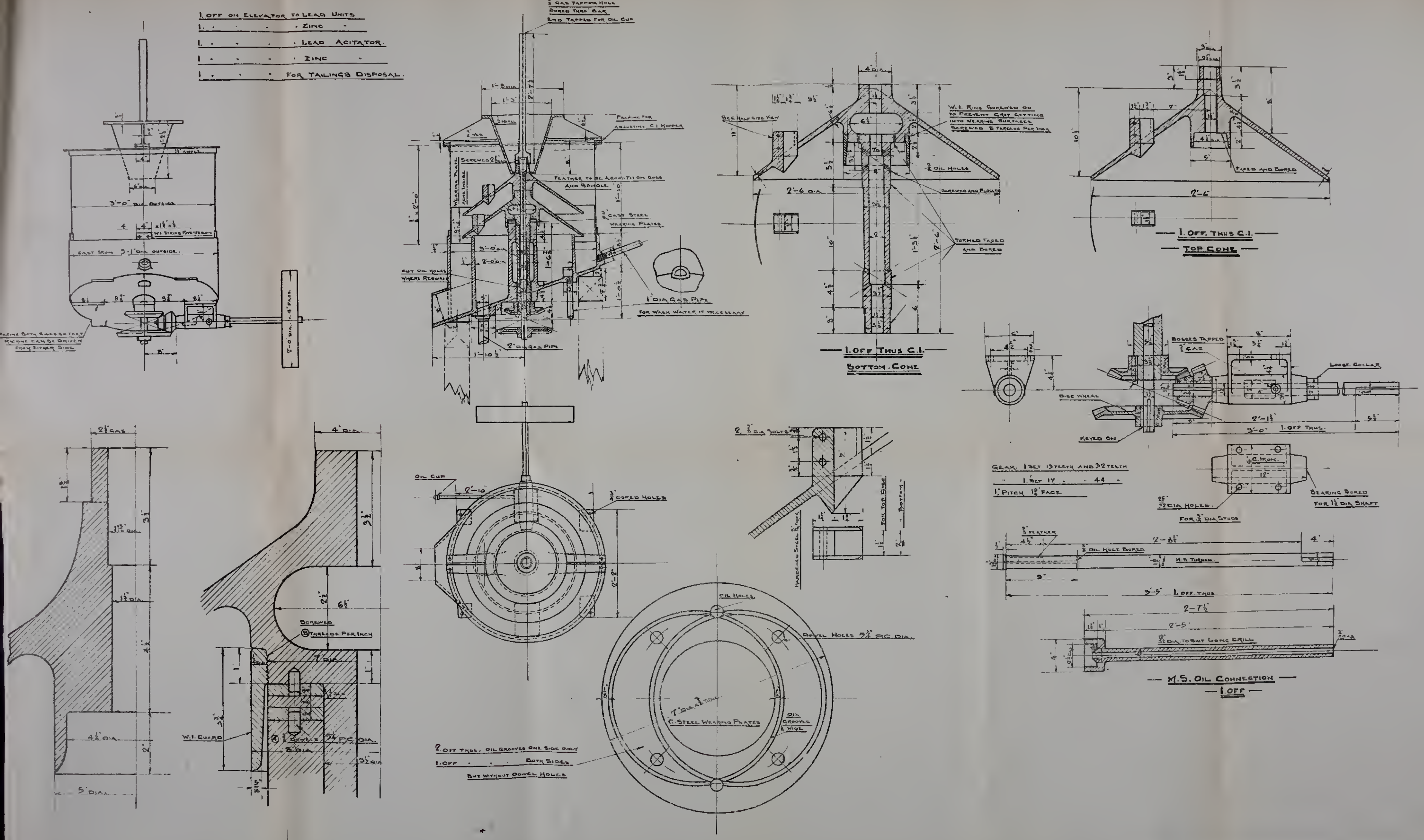


FIG 25.


½" DIA R H SCREW
⅜" × 3 MILD STEEL
10" OUTSIDE DIA
No. 20 GAUGE COPPER
BRASS
4-¼" WEBS
SOLDERED JOINT
BRASS
1'-0" DIA
1" DIA. W.I. PIPE
1'-5½"
6" DIA
MILD STEEL
1" GAS TAPPING
NOTE! VALVE FACE TO BE MACHINED ON SPINDLE [redacted] RADIAL GROOVES TO BE CUT ON FACE OF VALVE.
4-⅝" DIA BOLTS 3¾" LONG ON 4½" DIA P.C.
2" DIA
4½" P.C. DIA
¾" DIA W.I. PIPE 1¼" LONG
END OF SPINDLE SCREWED ¾" WHITWORTH AND RIVETED OVER
COPPER FLOAT
1'-5¼"
1'-1¼" DIA
⅝" DIA BOLTS
CAST IRON
2" DIA W.I. PIPE
1'-5"
NOTE! USE EXISTING CAST IRON BODY OF EXPERIMENTAL CONTINUOUS FLOTATION UNITS DRAWING No. 1663 MODIFIED AS SHOWN.
25' 0¾" DIA
FOR DISCHARGE VALVE SEE DRAWING No. 1730.
2" DIA W.I. PIPE
SLICE VALVE SEE DG No. 2219.
4" DIA PIPE TO MAIN LAUNDER
DORR THICKENER
25'-0" DIA
TIMBER TO SUIT WORK
⅝" DIA BOLTS TO SUIT
⅜" DIA No. 3 LENGTH TO SUIT
4-¼" WEBS
2" SQUARE
⅜" GAS TAPPING TO TAKE ⅜" TO 2" BUSHING
5"
5"
2" DIA
¼" M S BLANK
2" DIA
6" DIA
4-11/16" DIA HOLES ON 4½" DIA P.C.
C.I. SEATING OF SLICE VALVE DG No. 2219 BOLTS TO THIS FLANGE
2-13/16" DIA HOLES ON 6" P.C.
8" DIA
C.I. CROSS. 2 OFF.
PATENT No. 9470 . 1918.

DORR THICKENER FLOAT CONTROL.


1. OFF ON ELEVATOR TO LEAD UNITS
1. " " " ZINC "
1. " " " LEAD AGITATOR.
1. " " " ZINC "
1. " " " FOR TAILINGS DISPOSAL.
3'-0" DIA. OUTSIDE
4 4" x 1½" x ½" W.I. STRIPS RIVETED ON
CAST IRON 3'-1" DIA. OUTSIDE
FACING BOTH SIDES SO THAT MACHINE CAN BE DRIVEN FROM EITHER SIDE
2'-0" DIA. 4" FACE
⅜" GAS TAPPING HOLE BORED THRO' BAR END TAPPED FOR OIL CUP
PACKING FOR ADJUSTING C.I. HOPPER
FEATHER TO BE A GOOD FIT ON BOSS AND SPINDLE
⅜" CAST STEEL WEARING PLATES
CUT OIL HOLES WHERE REQUIRED
1" DIA GAS PIPE FOR WASH WATER IF NECESSARY
2" DIA GAS PIPE
SEE HALF SIZE VIEW
W.I. RING SCREWED ON TO PREVENT GRIT GETTING INTO WEARING SURFACES SCREWED 8 THREADS PER INCH
OIL HOLES
SCREWED AND PLUGGED
TURNED FACED AND BORED
2'-4 DIA.
1. OFF THUS C.I.
BOTTOM CONE
FACED AND BORED
2'-6"
1. OFF. THUS C.I.
TOP CONE
BOSSES TAPPED ⅜" GAS
LOOSE COLLAR
DISC WHEEL
KEYED ON
2'-1½"
3'-0"
1. OFF THUS.
GEAR. 1 SET 13 TEETH AND 32 TEETH
" 1. SET 17 " 44 "
1" PITCH 1½" FACE
C. IRON.
BEARING BORED FOR 1½ DIA SHAFT
25/32 DIA HOLES FOR ¾ DIA STUDS
⅜ FEATHER
OIL HOLE BORED
M.S. TURNED.
9'-5" 1. OFF THUS
2'-7½"
2'-5"
13/32 DIA TO SUIT LONG DRILL
M.S. OIL CONNECTION
1. OFF
2 ¾" DIA BOLTS
HARDENED STEEL
FOR TOP DISC
" BOTTOM "
OIL CUP
2'-10"
¾" CORED HOLES
2'-2"
OIL HOLES
DOWEL HOLES 9¾" P.C. DIA.
7" DIA ⅜" THICK
C. STEEL WEARING PLATES
OIL GROOVES ⅛ WIDE
2. OFF THUS, OIL GROOVED ONE SIDE ONLY
1. OFF " " BOTH SIDES
BUT WITHOUT DOWEL HOLES
2½" GAS
4" DIA.
6½"
SCREWED 8 THREADS PER INCH
7" DIA.
W.I. GUARD
4 ⅜" DOWELS 5¼" P.C. DIA.
8" DIA.
3½" DIA.
4½" DIA.
5" DIA.

PULP SAMPLING MACHINE.

to be sampled, and discharges a certain section of the slime pulp to the lower cone through an opening. The sample taken by this cone is a continuous one. The bottom cone, which revolves in the opposite direction to the top one, receives the cut from the top cone, on its upper surface, and a further fraction of the sample is cut out by the cutter, and opening provided, and discharged into a suitable container, while the main pulp stream overflows the edge of the cones into the body of the machine and is delivered to a launder. The cut taken by this lower cone is intermittent, and the position at which this sample is taken has a rotary cycle. In this way irregularity of flow over the cones is averaged. The two cones are contained in a cast-iron casing suitably arranged to carry away the main pulp stream. The work done by the machine is good, and gives an excellent check on the tonnage treated. Similar machines are placed on the residue discharge and concentrate discharge elevators.

Dorr Thickener Dischargers.—Float-controlled discharge valves for discharging the Dorr thickeners are employed on all Dorr thickeners. These are the invention of Mr. J. C. Cunningham (Patent No. 9470, 1918). Fig. 25 illustrates the apparatus and its application. Users of Dorr thickeners know the trouble that occurs when regulating the discharge by a man. Twisted shafts and such like are not unknown. The automatic apparatus illustrated still requires to be watched by an operator, in case of chokes occurring. Its function is to increase the discharge opening when an increased quantity of pulp settles on the bottom of the thickener. The principle involved is as follows :—For a given opening a certain quantity of pulp of a fairly uniform density will be discharged. If an increased tonnage be passed into the thickener there will be a gradual increase in the density of the pulp in the thickener, which causes the float of the apparatus to rise, and opens the valve further. The density of pulp discharged is varied to suit plant operations by loading the float to the desired extent. In practice it is found that the density is closely controlled by the apparatus. This is, in flotation plants, a feature of considerable importance.

Grade of Concentrate and Recovery from Current Slime.—From the inception of flotation in July, 1916, to May, 1919, the following are the tonnages of current slime treated with the lead section of the flotation plant :—

TABLE IX.

—	Tons.	%	Assay.			Recovery.		
			% Pb.	Oz.Ag.	% Zn.	% Pb.	Oz.Ag.	% Zn.
Lead concentrate ..	12,706	14.3	61.2	46.9	8.4	80.5	83.6	9.1
Lead residue ..	76,241	85.7	2.5	1.5	13.9	19.5	16.4	90.9
Total	88,947	100	10.9	8.0	13.1	100	100	100

The grading analysis of the lead concentrate shows that the bulk of the lead is —200 mesh I.M.M. screen less than .063 mm., the following being a typical grading analysis :—

—	Aperture in mm.	% weight.	Assay.			Proportion.		
			% Pb.	Oz. Ag.	% Zn.	% Pb.	% Ag.	% Zn.
+ 200 ..	.063	.5	13.0	4.6	4.9	.1	.1	.3
– 200 ..	.063	99.5	61.5	47.1	8.4	99.9	99.9	99.7
		100	61.2	46.9	8.4	100	100	100

Sectional Samples taken from the unit show a gradual decrease in the assay value of both concentrate and residue.

The following is a typical set of figures :—

—	Assay.		
	% Pb.	Oz. Ag.	% Zn.
Feed, 9 tons per hour	10.5	8.0	13.0

Products.	Concentrate.			Residue.		
	Assay.			Assay.		
	% Pb.	Oz. Ag.	% Zn.	% Pb.	Oz. Ag.	% Zn.
Cell No. 1 ..	74.4	63.6	2.8	9.8	6.8	13.1
,, No. 2 ..	74.0	58.0	3.0	8.9	6.0	13.4
,, No. 3 ..	70.8	54.4	4.5	7.7	4.8	13.2
,, No. 4 ..	70.8	52.0	4.7	6.7	4.4	13.3
,, No. 5 ..	65.0	49.0	5.2	5.0	3.2	13.6
,, No. 6 ..	60.0	44.4	6.6	4.2	2.6	13.6
,, No. 7 ..	58.2	45.2	7.1	3.7	2.4	14.1
,, No. 8 ..	50.8	40.0	10.5	2.4	1.6	13.8
,, No. 9 ..	35.0	26.0	14.9	1.8	1.2	13.8

Composition of Flotation Concentrate.—The following analyses show the typical composition of the flotation lead concentrate produced from current slime :—

		%
	SiO_2	3.00
	Pb	61.10
	Cu	1.10
Ag, 46 oz.	As	.06
	Sb	.28
	FeO	4.10
	Al_2O_3	1.60
	MnO	1.90
	CaO	2.40
	CO_2	1.40
	S	14.80
	Zn	8.40
	Total	100.14

NOTES ON THE SILVER VALUES OF THE CRUDE ORE.

The preferential flotation of the crude slimes shows that the mineral carrying the silver value of the crude ore is either a separate, easily-floated sulphide, or is closely intermixed with the galena. This point was considerably cleared up during some tests made on some fine material classified out from the zinc tails. This material was preferentially floated in a cascade box. The concentrate separating out in the launder had a brassy appearance and had the following assay :—

47 % Pb, 65.2 oz. Ag, 11.2 % Zn, 4.7 % Cu.

This concentrate was carefully graded and assayed, the results being :—

—	% weight.	Assay.			
		% Pb.	Oz. Ag.	% Zn.	% Cu.
+60 ..	3.0	3.0	123.8	10.1	14.2
+100 ..	7.0	6.6	140.0	16.5	15.5
+120 ..	4.0	9.9	107.4	23.0	13.1
+150 ..	5.0	14.3	91.8	27.3	10.1
+200 ..	11.0	32.0	73.8	12.7	7.8
−200 ..	70.0	59.4	50.4	9.0	2.5
	100.0	46.8	65.9	11.8	5.1

These figures plainly show that the silver follows the copper, the copper mineral being chalcopyrite. Later tests show the silver rising up to 320 oz. per ton in the sized products, a typical test being—

Average lead concentrates—

59.4 % Pb, 82.4 oz. Ag, 8.4 % Zn.

Sizing Test:—

—	% weight.	Assay.		
		% Pb.	Oz. Ag.	% Zn.
+60 ..	1.5	2.0	137.2	11.8
+80 ..	1.0	4.0	318.7	20.0
+100 ..	1.0	4.0	321.1	20.7
+120 ..	1.5	5.4	280.3	21.0
+150 ..	.5	12.8	223.4	20.3
+200 ..	2.5	18.0	201.1	22.4
−200 ..	92.0	63.0	68.0	8.5
	100.0	58.5	81.3	9.4

The copper present in this sample was not determined.

Considerable quantities of the mineral pyrrhotite were present in these samples, and, as silver has been found associated with pyrrhotite in the Broken Hill district, the mineral pyrrhotite was separated from the concentrate by a magnet and assayed for silver, the result being 7.0 oz. per ton.

The recovery of silver in the gravity concentrating mill is not high, owing to the losses in the slime produced, and in the close intermixing of the silver-carrying minerals with the blende in the tailing product. If these products—*i.e.*, zinc tailing—were more finely ground and preferentially floated, much more of the silver could be recovered than at present.

Circuit Water.—The water used in the flotation circuit consists of water pumped from the underground workings, and a small addition of fresh water from the town mains. The circuit liquor is always run at approximately 22° C., and is alkaline to methyl orange.

The following is a typical analysis of the circuit liquor :—

	Grains per gallon.
Total	368
SiO_2	1.6
$Fe_2O_3Al_2O_3$	4.2
MnO	15.4
ZnO	8.7
CaO	52.7
MgO	10.1
SO_3	144.3
Cl	52.9
CO_2	3.5
Na_2O	49.3
K_2O	17.7
Water of crystallization	21.6
	382.0
Less oxygen equivalent to Cl	11.9
Total	370.1

RESIDUES FROM FLOTATION PLANT.

The residue from the lead section of the flotation plant, which has an average assay of 2.5 % Pb, 1.5 oz. Ag, 13.9 % Zn, is, for the present, stored in a dam. The method of building the dam is practically the same as that outlined in an excellent number of articles on slime dams, their construction and maintenance, by J. E. Thomas and E. A. Ostenleigh, in the *Journal of the Chemical, Metallurgical, and Mining Society of South Africa*, beginning in June, 1917.

Treatment of the Lead Residue.—The residue contains approximately 90 % of the zinc contained in the slime, and has an average assay of 13.9 % Zn. It will be seen from the analyses of the slime that it contains a large percentage of calcite, which, in the ordinary zinc flotation practice used on this field, is an acid consumer.

Shortly after the completion of the lead unit, a similar unit was completed for the treatment of the residue from the lead section, in order to produce a zinc concentrate and a valueless residue.

The zinc unit was run experimentally for three months, testing out the method of treatment indicated by the laboratory and one-ton unit results.

The final set of reagents worked out for the treatment of this calcitic residue are small quantities of eucalyptus oil, copper sulphate, and sulphuric acid in a cold circuit—*i.e.*, 27° C.

The experiments on zinc flotation were brought to a successful issue in February, 1917.

On account of the war, the maximum production of lead from this field was required. Owing to a shortage of labour, both the construction of new plant and the breaking of larger tonnages of crude ore from underground to keep the gravity concentrator running at full capacity were very much hampered, and to increase the production of lead concentrate the above zinc flotation section was placed in commission to treat the accumulated dump slime.

In doing this, lead concentrate only was produced, and the zincy residues from both slime flotation plants were stored in dams.

COMBINED GRAVITY AND FLOTATION MILL RECOVERIES ON CRUDE ORE TREATED.

Table X. shows the total recoveries, assays, &c., made by gravity and flotation concentration for the period January, 1917, to May, 1919 (inclusive).

During this term the whole of the slime produced was treated by the flotation process for the production of a lead concentrate.

TABLE X.

—	Tons.	% prop.	Assay.			Proportion Recovery.		
			% Pb	OzAg	%Zn.	% Pb.	% Ag.	% Zn.
Jig concentrate ..	39,243	8.09	69.4	23.8	6.5	38.7	26.0	3.9
Table concentrate ..	38,952	8.04	63.6	24.0	8.8	35.0	26.4	5.0
Flotation concentrate	10,782	2.23	61.8	48.2	8.2	9.5	14.4	1.3
Total lead concentrates	88,977	18.36	65.8	26.4	7.6	83.2	66.8	10.2
Zinc tailing	284,327	58.66	3.3	3.5	17.2	13.5	28.2	72.8
Quartz tailing ..	46,763	9.66	1.5	1.4	5.3	1.0	2.0	3.7
Flotation residue ..	64,523	13.32	2.5	1.6	13.9	2.3	3.0	13.3
Total crude ..	484,590	100	14.5	7.3	13.9	100	100	100

TREATMENT OF DUMP SLIME—ARRANGEMENT OF FLOTATION UNIT.

The flotation cells for treating the dump material are similar to those treating current slime.

In this plant there are nine flotation cells, seven of which are in series with a mixer vessel, and two are arranged to refloat the dirty concentrate from the sixth and seventh cells of the series.

The last re-floating cell is connected by a 4-in. pipe to the inlet pipe of the first cell of the series. By this arrangement the re-float residue is drawn back into the first flotation cell by the pump impeller, making a very compact and neat arrangement. The arrangement is shown in Fig. 24.

Practice of Treatment.—The early laboratory and one-ton unit tests show that approximately 60 % of the lead and 65 % of the silver could be recovered on slime from the dump that had not become air-dried or weathered.

Breaking and Transporting Slime to the Plant.—It was decided that the dump adjacent to the flotation plant, containing 350,000 tons of slime, and having an average height of 30 ft., was to be treated.

A sluicing scheme was finally decided upon for the removal and transport of this slime to the plant, which is novel for this field. At the dump the slime is broken down with two 1-in. monitors operating at a pressure of 80 lb. per sq. in. The pulp formed varies from 10 % to 15 % solids by weight, and is gravitated to a pair of Gould 4-in. centrifugal pumps. The pump and pits are placed 10 ft. below the surface level of the ground, the pressure of water for the monitors being provided by a Kelly and Lewis 6-in. centrifugal pump.

The pumps deliver the pulp to two 25-ft. and one 20-ft. Dorr thickeners; the clear overflow flows to the mill sumps or mill dams as required. The monitors disintegrate the interior portions of the dump slime into practically its original slime condition. The hard outer crusts are broken into little, hard, round pellets, approximately $\frac{1}{8}$ in. to $\frac{1}{4}$ in. diam. These small pellets of slime are carried along with the pulp and discharged over a screen on the down pipe of the thickeners, which takes out all above $\frac{1}{8}$ in. diam.; the plus $\frac{1}{8}$ in. material is subsequently crushed through the screen.

The thickened pulp flows from the thickeners through a tube mill, where the small hard pellets of slime are ground up. The pulp is then elevated to the mixer vessel of the flotation plants, where a small quantity of eucalyptus oil is added and beaten in.

The pulp then passes over a sampling machine in order to take a tonnage and assay sample. From the sampling machine the slime pulp gravitates to the flotation cells, where a lead concentrate is floated off.

The consumption of eucalyptus in this plant is .03 lb. per ton of slime treated.

Disposal of Concentrates.—These are sent to a storage agitator and filter-pressed in Dehne presses, as described under current slime.

Disposal of Residues.—These are disposed of in the same manner as the residues from the current slime.

Grade of Concentrates and Recovery from Dump Slime.—Table XI. shows the tonnages of dump slime treated, with assays and recoveries, from the inception in February, 1918, to May, 1919 :—

TABLE XI.

—	Tons.	% prop.	ASSAY.			PROPORTION.		
			% Pb.	Oz Ag.	% Zn.	% Pb.	% Ag.	% Zn.
Lead concentrate	7,219	13.86	51.1	44.8	14.4	61.7	75.3	14.6
Lead residue ..	44,842	86.14	*5.1	2.4	13.5	38.3	24.7	85.4
	52,061	100	11.5	8.2	13.6	100	100	100

* The residue contains 2 % Pb in the oxidized state.

The following are typical assays obtained by sectional sampling of the unit :—

—	No. of Cell.	ASSAY.		
		% Pb.	% Ag.	% Zn.
	1	61.6	56.0	11.2
	2	57.4	46.4	12.6
	3	48.0	36.6	15.4
	4	38.4	28.8	21.0
	5	32.0	22.0	22.9
Refloat concentrate from Nos. 4 and 5 cells	6	48.0	37.2	15.0
	7	44.0	36.0	16.1

EXPERIMENTAL LABORATORY.

An experimental laboratory for testing and investigating problems contingent to the process is maintained at the mine, and is attached to the assay office. It is directly under the charge of the metallurgist.

This laboratory is equipped with two experimental machines, as shown in Fig. 14, and two smaller machines made from drawings (Fig. 22). One of each of these machines is constructed of cast iron, the other of brass. The reason for this is the difference in the behaviour of blende when treated in a brass or iron vessel.

In addition to the sub-aeration flotation machine, the laboratory is fitted with a small Pachuca tank, Callow cell, and a Braun K. and K. flotation machine. Gas, air, steam, and cold water are laid on to the building.

LABOUR.

The staff for operating the concentrating mills and flotation plants comprises :—

Chief metallurgist.
Assistant metallurgist.
Milling foreman.
3 mill shift bosses.
3 jig bosses.
Foreman fitter.

The general labour for operating mills per 24 hours is as follows :—

Gravity Concentrating Mill.

	Men.	Boys.
Cracker feeding	4	—
Crude ore conveyor	3	3
Rolls	3	3
Jigs and plugs	—	3
Grinding pans	3	—
Trucking lead concentrate	3	—
Wilfley table attendants	12	—
Oilers	3	3
Water circulation	3	—
Motor drivers	3	—
Engine drivers	3	—
Samplers	1	1
Fitters	2	—
Mill repairers	3	—
Fitters' labourers	3	—
General labourers	5	—

Slime Flotation Plants (Current and Dump Treatment).

Flotation cell men	6	—
Feed Dorr thickeners (attendants)	3	—
Residue Dorr thickeners (attendants)	3	—
Oilers	3	—
Filter press attendants	4	—
Sluice men, dump slime	3	—
Slime residue disposal	3	—
Labourers	3	—
Fitter	1	—
Fitter's labourer	1	—
Motor drivers	3	—

TREATMENT COSTS, GRAVITY MILL.

Table XII. gives segregation of treatment costs during the two half years ended 30/6/1911 and 31/12/1911, and shows that costs were on a satisfactory level. The plant was running at full capacity, the rate of treatment being—

6732 tons per week for half-year 30/6/1911.
6915 ,, ,, ,, ,, 31/12/1911.

The basic wage was then 9s. 6d. per shift of 8 hours, and the weekly hours 48.

Prices for stores were at normal figures.

TREATMENT COSTS, GRAVITY AND FLOTATION MILL.

Table XIII. shows particulars of the treatment cost in all stages of the process for the half-year ended December, 1918. This period was chosen on account of being a period during which the plants were running continuously, but not to full capacity, and was free from strikes.

The average weekly tonnage of crude ore milled was 3750 tons, a little more than half of the rated capacity of the concentrator, the low tonnage being due to a shortage of miners on the field.

The basic wage at this time was 12s. per day; hours per shift, 8; and per week, 48.

Prices for stores were inflated, owing to the war, and from the same cause the number of men available for the industry had fallen so much that stoping operations underground were reduced from three to two shifts. The hours of work for miners were reduced from 48 to 44 by the award of Mr. Justice Higgins in 1916.

Table XII.

Treatment Costs for the Half-Years ended 30th June, 1911, *and 31st December*, 1911.

Cost per ton treated.

	Half-year ended 30/6/1911.	Half-year ended 31/12/1911.
Crude ore treated	175,044 tons...	181,790 tons.
Lead concentrate produced	26,617 ,,	27,339 ,,

—	Labour. d.	Stores. d.	Power. d.	Total. d.	Labour. d.	Stores. d.	Power. d.	Total. d.
Superintendence	3.0	—	—	3.0	2.9	—	—	2.9
Gates crushing	1.1	.7	.7	2.5	1.1	.8	.8	2.7
Crude ore conveying ..	.7	.5	.4	1.6	.6	.1	.4	1.1
Sampling	.4	—	.1	.5	.2	—	.1	.3
Rolls crushing	.9	.9	1.5	3.3	1.0	1.3	1.4	3.7
Raff elevators	.3	.3	.2	.8	.3	.4	.2	.9
Jigging and jig screens	.9	.5	.3	1.7	.8	.5	.3	1.6
Fine grinding	.5	2.7	3.8	7.0	.6	2.7	3.6	6.9
Pan elevators	.2	.2	2.0	2.4	.2	.4	1.9	2.5
Pan screens	—	.2	.2	.4	.1	.2	.2	.5
Wilfley tables	2.2	.6	2.4	5.2	1.8	.3	2.2	4.3
Wilfley elevators.. ..	.6	.5	2.3	3.4	.6	.5	2.2	3.3
Slime disposal	.4	.1	.1	.6	.1	.1	.1	.3
Quartz disposal	.3	—	.1	.4	.2	.3	—	.5
Zinc disposal	.3	.1	—	.4	—	.4	—	.4
Concentrates disposal ..	.9	.1	—	1.0	1.1	.2	—	1.3
Water circulation ..	.3	.6	1.9	2.8	.3	.3	1.7	2.3
Lighting and telephone..	.2	.2	.9	1.3	.2	.2	.9	1.3
Assaying	.5	.3	—	.8	.5	.4	—	.9
Sundries	1.9	1.1	.3	3.3	2.3	1.0	.3	3.6
Total	15.6	9.6	17.2	42.4	11.9	10.1	16.3	41.3

Broken Hill, 2nd August, 1921.

TABLE XIII.

Treatment Costs for the Half-Year ended 31*st December*, 1918.
Cost per ton treated.

CRUDE ORE.

Tons treated	97,510
Lead concentrates produced	16,208

—	Labour. s. d.	Stores. s. d.	Power. s. d.	Total. s. d.
Superintendence	7.6	—	—	7.6
Gates crushing	1.9	0.8	2.4	5.1
Crude ore conveying	1.3	0.7	0.3	2.3
Sampling	0.4	0.1	0.0	0.5
Roll crushing	1.6	1.3	4.2	7.1
Raff elevators	0.6	1.5	0.5	2.6
Jigging and jig screens ..	0.8	0.3	0.3	1.4
Fine grinding	1.2	3.9	10.8	1.39
Pan elevators	0.3	0.7	5.6	6.6
Pan screens	0.1	0.4	0.5	1.
Wilfley tables	3.8	1.0	1.1	5.9
Wilfley elevators..	1.5	0.8	1.6	3.9
Quartz disposal	0.2	0.1	—	0.3
Zinc disposal	0.3	1.0	—	1.3
Concentrate disposal	1.7	0.6	—	2.3
Mill water circulation	1.7	0.9	1.8	3.4
Lighting and telephone.. ..	—	—	1.8	1.8
Assaying	1.1	1.0	—	2.1
Sundries	9.8	4.5	0.7	1/3.
Grand total	2/11.2	1/7.9	2/8.1	7/3.2

CURRENT MILL SLIME.

Tons treated	15,567
Lead concentrates produced	2,278

—	Labour. s. d.	Stores. s. d.	Power. s. d	Total. s. d.
Superintendence	0.8	—	—	0.8
Sluicing	—	—	—	—
Treatment	1/3.4	11.3	4/5.7	6/8.4
Disposal of residue ..	6.4	2.0	2.3	10.7
Filter-pressing	4.1	6.5	0.8	11.4
Concentrate disposal ..	1.2	—	—	1.2
Sundries	1.8	5.9	1.8	9.5
Grand total	2/5.7	2/1.7	4/10.6	9/6.0

ACCUMULATED DUMP SLIME.

Tons treated	21,055
Lead concentrate produced..	2,977

—	Labour. s. d.	Stores. s. d.	Power. s. d.	Total. s. d.
Superintendence	0.6	—	—	0.6
Sluicing	7.9	7.5	—	1/3.4
Treatment	7.2	3.3	3/8.2	4/6.7
Disposal of residue ..	6.1	1.6	2.7	10.4
Filter-pressing	3.7	5.9	0.8	10.4
Concentrate disposal ..	1.2	—	—	1.2
Sundries	1.4	5.4	1.0	8.1
Grand total	2/4.1	1/11.7	4/1.0	8/4.8

CONCLUSION.

The milling practice described in the foregoing pages may be regarded as typical for the recovery of galena in the form of a concentrate from Broken Hill ores. The main modification to bring the description into line with other mills is the substitution of tube mills for grinding pans for the grinding of the jig tailing for table treatment.

Most of the other companies recover the blende in the form of a flotation zinc concentrate from the table tailing. This is not done at present by the South Co. For the time being the South Co. has a contract with Amalgamated Zinc (De Bavay's) Ltd. for the treatment of the table zinc tailing for the production of zinc concentrate. In the treatment of slime a few companies are treating their slime products by Bradford SO_2 and $CuSO_4$ processes, with excellent results.

The plants of the Broken Hill South Ltd. were constructed under the supervision of the general manager, W. E. Wainwright, and were designed by the company's chief engineer, J. C. Cunningham. The metallurgical experimental work and the superintendence of milling operations up to 1915 were under the care of the company's chief metallurgist, W. J. M'Bride, who in that year joined the A.I.F., and became a captain in the First Tunnelling Company, France, and subsequently returned to Australia and the South Co. in 1919. During the absence of the chief metallurgist with the A.I.F. his work was carried on by T. A. Read, the company's assistant metallurgist.

MECHANICAL METHODS OF ALLAYING DUST.

By P. H. Warren.

(Discussion.)

Mr. P. H. Warren in his final reply to discussion said that Mr. Fairweather, at the Institute meeting on 21st June, drew attention to the fact that the modern rock-drill should be regarded as a mechanical dust-allayer. It was thought, however, that members interested in the subject would be sufficiently conversant with the general operation of rock-drills to make a detailed description of constructional features unnecessary. Attention was therefore concentrated upon the relative efficiency of the different types of machines in their respective dust-allaying capacities. He (the author) nevertheless agreed with Mr. Fairweather that the literature upon the subject of rock-drills could be added to in the light of present-day knowledge and requirements. In touching lightly upon the subject, he would like to say that, in his opinion, the rock-drill of the future for stoping and driving work would be the axial water-feed machine, not only because it was so much lighter than the reciprocating machine, and on account of the greater ease in collaring holes, and its higher boring speed, but in the matter of dust-allaying it was not dependent upon a man with a jet, and therefore never bored dry unless the water supply were interfered with. Other things being equal, the quantity of dust made by hammer drills was proportional to the quantity of exhaust air allowed to pass through the hollow steel to the bottom of the hole. The truth of that statement had been demonstrated on the South mine. Whereas, in the case of axial water-feed machines of the Leyner type, the passage of water through the steel kept the dust in check, dry-head jack-hammers were dependent upon water externally applied, and, in his experience, invariably showed high dust counts when reliance was placed on the outside jet alone. The various forms of the Clifton apparatus had been developed to meet that difficulty, and, while the Clifton had proved its superiority over the outside jet, as before stated, the quantity of dust getting away would depend on the quantity of exhaust air passing through the hollow steel. Fig. 1 showed a modified form of Clifton apparatus called the disc type, which the South mine was using for all popping work. It was smaller, permitting of shorter steels being used, and was

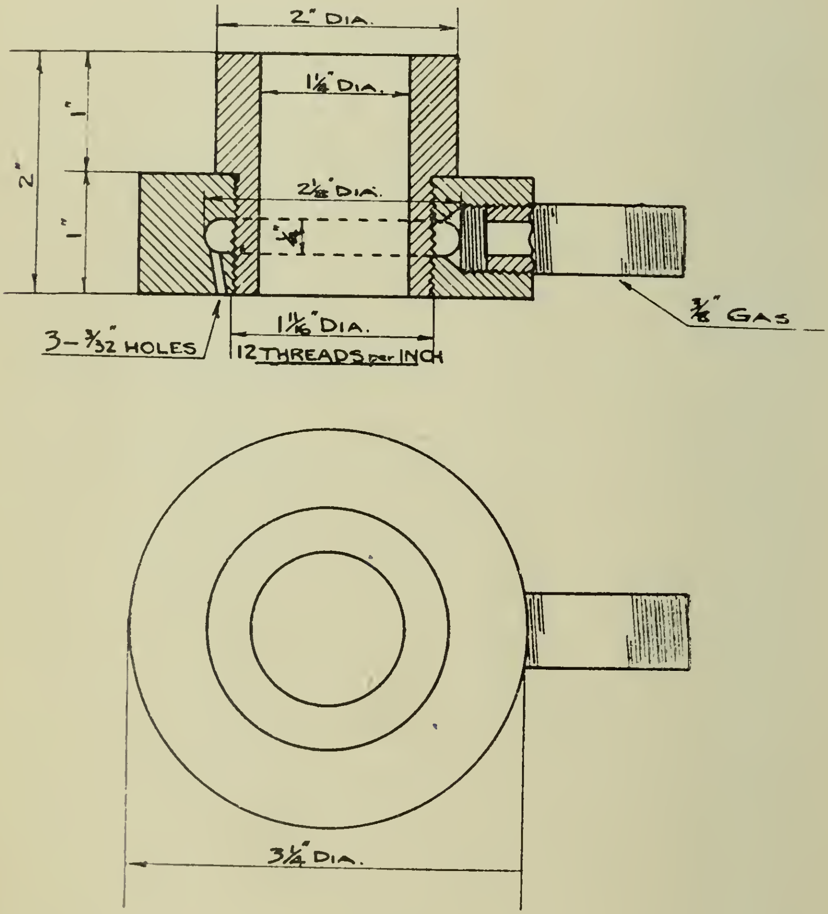
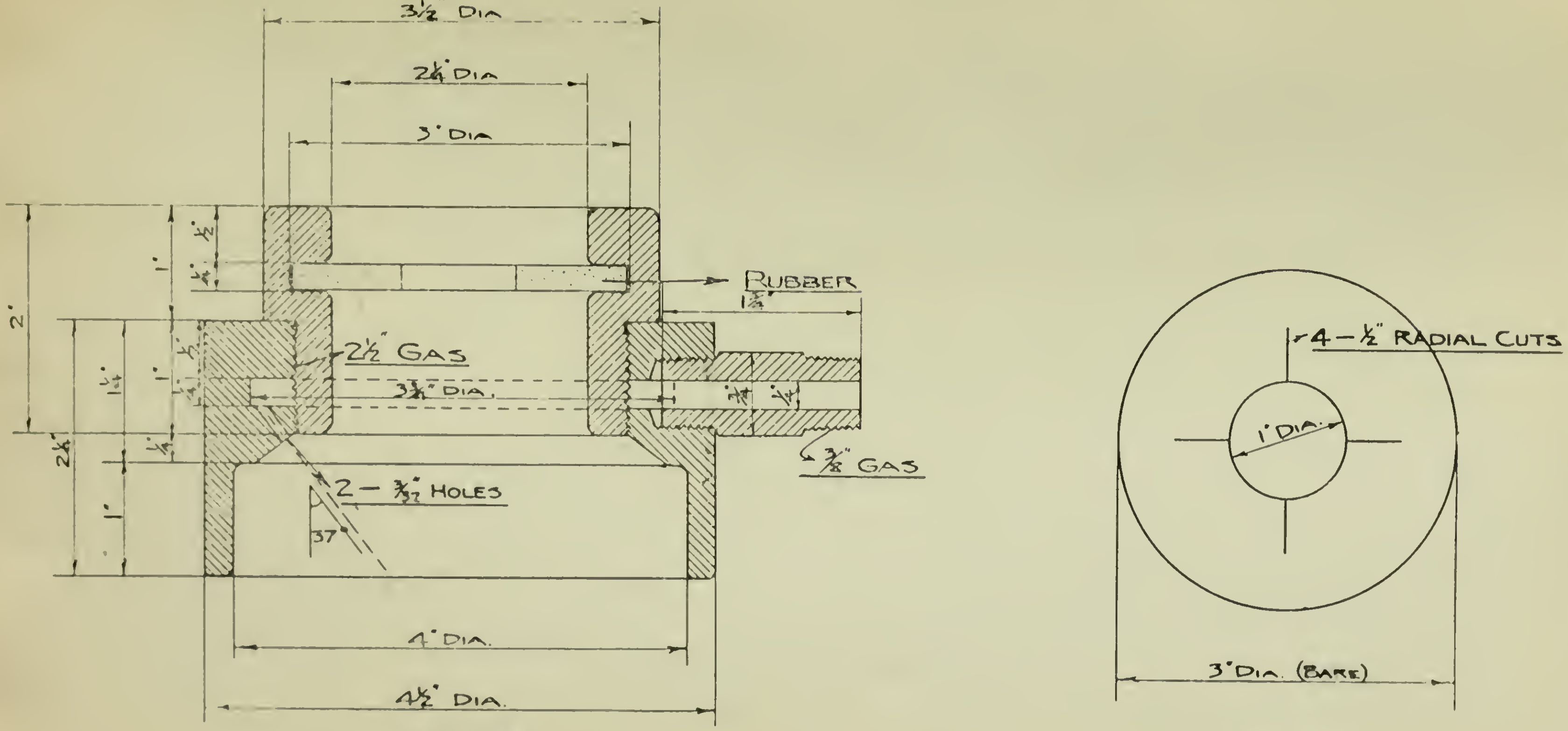


FIG. 1.
IMPROVED POPPER—CLIFTON DISC TYPE.

more durable than that shown in fig. 3 of the original paper. Fig. 2 was a development of the apparatus for use with jack-hammers in winze sinking; the hole at the top, being 2¼-in. diam., allowed the use of collared steel. He had not yet found an axial water-feed machine that gave low dust counts on rise holes—an axial water-feed



SECTION.

RUBBER DISC

Fig. 2.
Improved Popper Clifton for use with Collared Steel.

machine being one in which the water passes through the hammer—and those machines possessed the additional disadvantage of being very wet to work under. Those facts, together with the encouraging results obtained from experimental use of Clifton's apparatus, as illustrated in fig. 2 of the original paper, on rise holes, with dry-head hammer machines, justified them in developing that line of attack. In passing, he would like to say that it was hardly fair to the apparatus to test it with cruciform steel, as he believed was done in the case of the Zinc Corporation test mentioned by Messrs. Clayton and Hanton. A great deal had been said in opposition to the suggestion to use water blasts on a comprehensive scale, but, as Mr. Fairweather had pointed out, the argument had never passed beyond the stage of assertion, unsupported by conclusive proof that such practice would result in prohibitive expense, or would adversely affect the conduct of mining operations in any way. Dealing first with the subject of humidification of mine air due to use of water blasts, he was afraid Mr. Clayton must have misread the writer on that subject. He (Mr. Clayton) accused the author of having said "The water blast did not practically saturate," and later, "Surely Mr. Warren was not contending that water blasts did not increase the humidity of the air." Both in the original paper and in reply to discussion at a subsequent meeting the writer admitted that the use of water blasts would produce temporarily an increased degree of humidification of the air in the places where they were used. When they first started installing water blasts they, in common with others, believed that the increased humidity was likely to prove a serious obstacle to their use, but those fears had not been realized, as the figures showing the relative humidity of the air in working places, quoted on page 91 of the Proceedings (No. 42), showed. He wished to again emphasize the statement that humidification, and its effect on mine workers, was dependent upon factors such as the depth of the workings, amount and moisture content of rock face exposed, moisture contained in the filling, and temperature of the air. It was essential, in their own interests, that they provided sufficient ventilation to enable the men to work in reasonable comfort. The increased humidification due to water blasts, occurring, as it did, at intervals only, and then while the men were not actually in the face, could easily be dealt with. In any case, humidification could have no serious effect, provided the wet-bulb temperature be kept sufficiently low—a condition which could easily be obtained in any Broken Hill mine. The following example was based upon the conditions existing at the South mine:—Assume that there were 60 water blasts in the mine, averaging 15 minutes' running time each per 24 hours. Taking the water consumption of each blast at 2 gal. per minute, and using Mr. Clayton's figure of 1 lb. of water to 560 cub. ft. of air, they would fog 10,080,000 cub. ft. of air, which was about one-twentieth the quantity of air handled by the fan in the 24 hours. The following test was also of interest:—

Humidity Test after Water Blasting in Dead-end Drive 150 *ft. away from Nearest Through Air Current.*

Time.	Wet.	Dry.	Remarks.
9.45 a.m.	61° F.	66° F.	Before water blast started.
9.50–10.00	—	—	Water blast full on.
10.00	65	65	Water blast stopped.
10.5	65	65½	
10.10	64½	66	
10.15	63½	66	
10.20	63	66	
10.25	62	66	

It would be seen from the above test that the humidity ratio of the air in the place had become nearly normal 25 minutes after the water blast had stopped. If the contention that the use of water blasts on a big scale had a serious effect on the quality of mine air were true, should they not be able to detect it at present in the South mine? It frequently happened that 15 or 20 blasts might be in operation for 15 minutes during the day. The following figures were therefore presented as showing that water blasting did not produce any serious increase in humidity:—

Classification.	Wet.	Dry.	Relative Humidity.
1. General stope average, Aug., 1920	70½	73	86%
2. Average working places, Aug., 1921	68½	71	85½
3 Average stopes, 425–970, Aug., 1921	73	76½	81½
4. ,, ,, 1918	79½	81½	90

The quantity of moisture in the mine air in 1918, when no water blasts were used in stopes, was greater than at present. The ventilation system had, during that period, received considerable attention, which accounted for the differences shown. He was quite in agreement with Mr. Clayton's statement that dust should be completely removed from the mine, so that men could not come into contact with it, but he was afraid that in most metalliferous mines—certainly in their own case—the practical realization of that excellent ideal presented difficulties which made it impossible of achievement. As an illustration of that, the air which leaves their stopes on the 1270-ft. level opposite No. 1 shaft had to traverse 15 working faces before it could reach the upcast. Gravimetric samples had shown that firing in sulphide stopes could produce quantities of dust up to 138 mg. per cub. metre (the tentative safety standard in South Africa is 5 mg. per cub. metre) obtained up to 30 minutes after the holes were fired. They were therefore faced with the necessity of doing something to prevent men breathing air so heavily charged with dust. Fortunately for them, the local conditions as regards fibrosis were very much more favourable than those obtaining in South Africa, but the chairman of the Broken Hill Technical Commission definitely stated that " a condition of pneumoconiosis arises among underground workers as a result of inhalation of dust." He (the author) would point out also that the companies were paying out considerable sums of money as compensation for both fibrosis and lead poisoning. They were therefore justified in adopting all reasonable measures to prevent the men from coming into contact with such dust. The following samples were taken gravimetrically in stopes, and represented weights of dust obtained up to 30 minutes after firing :—

Date.	Remarks.	Milligrams per Cub. M.	% Pb.
13/6/21	Fired 3 holes—no water blast	41.9	14.9
14/6/21	,, 6 ,, ,, ,,	138.0	18.3
16/6/21	,, 4 ,,	40.0	46.4
18/2/21	,, 3 side holes	69.0	31.9

He directed attention to the high percentage of lead in those samples. Tests had been submitted as showing that the water blast was effective in allaying dust. Particulars of the following test conducted by Mr. F. M. Murdoch and the author were given as conclusive evidence in support of the above contention. The accompanying sketch (fig. 3) shows the location of the test. Six holes 3 ft. deep were fired in each test, and the same quantity of explosive—viz., 12 lb. of 74 % gelatine dynamite—was used for each firing.

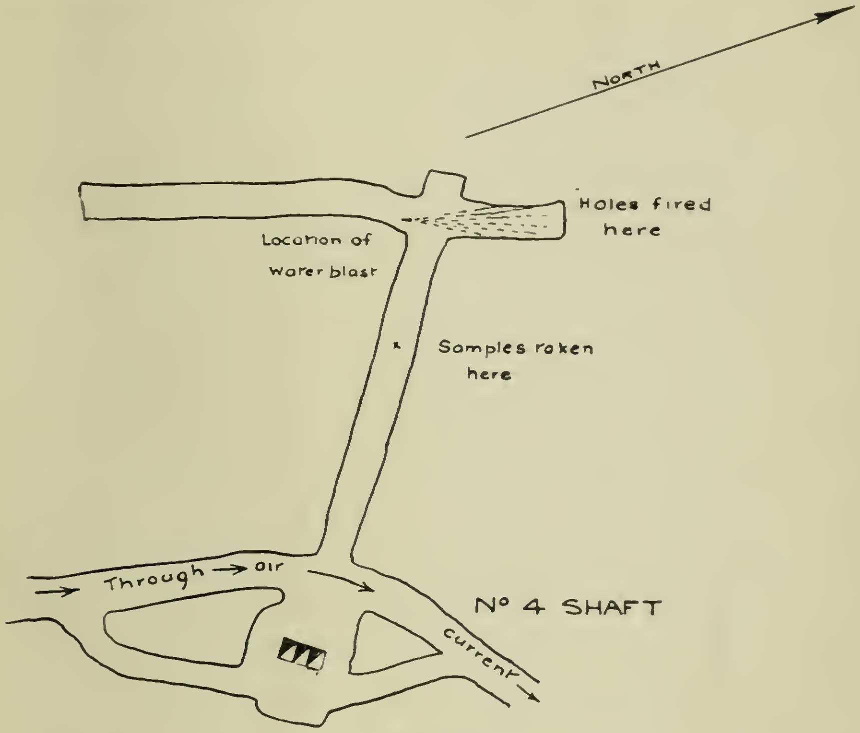


FIG. 3.

Time of Firing.	Water Blast.		Sample.		Milligrams of Dust per Cub. Metre of Air.	Percentage Reduction	Total Dust Particles per cc. Av. for Sample.	Percentage Reduction.
	On.	Off.	Start.	Stop.				
			p.m.	p.m.				
2.45 p.m. 14/10/21	None.		2.50	3.00	371.20	—	No spots	—
			3.00	3.15	157.00	—	,,	—
			3.15	3.45	35.00	—	1744	—
			3.45	4.15	7.60	—	283	—
	a.m.	p.m.	p.m.	p.m.				
11.56 a.m. 13/10/21	11.56	12.11	12.1	12.11	37.60	89.90	No spots	
			12.11	12.26	19.70	87.5	,,	—
	Ran for 15 mins.		12.26	12.56	10.90	68.9	654	62.5
			12.56	1.26	3.40	55.3	No spots	—

The foregoing comparison showed that the dust in the air in the second test up to 15 minutes after firing was only 1/10th that present in the first test, in which no water blast was used. Most of those members who have helped in the discussion were prepared to concede that water blasts could be used with advantage in dead-end places and over stope exits, such as winzes. The suggestion advanced in the original paper, that every stope face should be provided with a water blast, and that additional blasts should be provided over winzes, could be modified to read—" In stoping operations, water blasts should be provided where they can be used with advantage." He was quite prepared to admit that water blasts placed in large stopes could not be expected to lay dust with the same efficiency as would be the case in a small development end, but he must insist that the methods of mining in use at Broken Hill resulted in the existence of a large number of stopes that, by reason of the small area open at any time, could easily be covered by a water blast, and that contention was supported by Mr. Bridge. If, therefore, they wished to prevent concentrations of dust, resulting from firing stope faces, being carried by air currents to other working places, was it not reasonable to use any means they had at their disposal to cause such particles of dust to become wet and fall before they could reach other faces where men were at work ? Water blasts situated in stopes had one advantage over those situated over winzes, which should be mentioned. They were much more easily controlled, and could be attended by the miners, whereas, in the latter case, some special arrangement was necessary. Objection had been raised, on the score of expense, to the use of water blasts, though no figures had been supplied in support of that contention. The following was an estimate of cost for an installation of 70 blasts, which would be the number necessary in the South mine for a production of 6000 tons a week :—

Cost of each blast, C type, placed in stope, £2 7s. 2d.

70 x 47.16 = 3301.2.

Assume that all blasts were replaced once every two years, then

capital cost per year = 1650.6s.
,, ,, ,, week = 31.74s.
add 5 % interest charge = 1.58s.

33.32s.

Running Costs.—

Air.—Each blast runs for 15 minutes per shift, using 130 cub. ft. of air per minute, at a cost of 6d. per thousand cub. ft. of free air =

$$\frac{70 \text{ x } 130 \text{ x } 15 \text{ x } 1}{1000 \qquad 2} = 68.25\text{s. per day.}$$

Water.—Each blast uses 2 gall. per minute, at 5s. per thousand =

$$\frac{70 \text{ x } 2 \text{ x } 15 \text{ x } 5}{1000} = \frac{1050}{100} = 10.5\text{s. per day.}$$

	68.25
	10.50
	78.75
plus 10 % for labour	7.87
	86.62s. per day.

Weekly Cost.—Capital outlay	..	38.32s.
Running—86.62 x 5		433.10s.
		466.42s.

$$\frac{466.42\text{s. x } 12\text{d.}}{6000} = .92\text{d.}$$

say 1d. per ton, which, for a weekly production of 6000 tons, represented an outlay of considerably less than that necessary to pay insurance premiums against lead poisoning. He was in agreement with the remarks of Inspector Grey, as quoted by Mr. Voss Smith, concerning the tendency of a water blast system to operate very inefficiently. That has been borne out by his own experience. Water blasts could not be left to look after themselves, nor could they be left to the pipefitters' discretion. He had found that, unless carefully supervised, they will be wrongly located and pointed in such directions that they could not possibly do much good. It was, he thought, necessary to educate the shift bosses, who visited the working places twice a shift, concerning those matters, and that was being done. Each boss had been supplied with a sheet of instructions covering these and other matters connected with dust-allaying and ventilation.

Counting Dust Spots.—Messrs. Danvers Power, Whiteman, Clayton, Pearson, and Hanton had discussed the counting of dust spots obtained by the konimeter. The point at issue, he thought, was whether or not the konimeter in its present form could be regarded as an accurate scientific instrument. That matter had been fully discussed by the South African people, and many interesting arguments had been advanced for and against its use. Much of the success of that method of determining the dust content of air was left to the individual operator who counted the dust particles after the samples had been secured. Fortunately, that was a simple operation, and capable of great accuracy in the majority of cases where the number of particles did not exceed 450 per cc. When dealing with spots heavier than that, errors were likely to creep in, due to the formation of aggregates of dust particles, and also because all the dust might not be deposited upon the vaselined slide. Errors due to the latter feature might, to a certain extent, be modified by taking proper care of the instrument. The fact that the volume of air sampled was small (from 5 to 10 cc.) was no disadvantage when using a method which ultimately determined the dust content by counting. If a large volume of air were taken, it would be still necessary to count a small portion only, and the resulting error might be much more serious than if a number of small samples were taken and averaged. For the determination of dust conditions in a mine with a view to control and prevention, the instrument had great value and utility, inasmuch as it supplied a quick, ready, and reasonably accurate method of discovering what those conditions were. They used a konimeter made on the South mine, on the Kotze model (but with certain improvements designed to prevent leakage), to which was fitted a microscope, magnifying 146 diameters. Samples could thus be taken underground and at once counted with sufficient accuracy to determine whether the air was unduly charged with dust or not. Counts obtained in that way had checked, when counted under the higher-powered microscope, to within 20 %. Experience enabled him to say that counts of the same operation, such as boring with piston drills, taken in different parts of the mine at different times, have yielded results which vary little. In further elaboration of that point, it was interesting to note that the figures given in the paper for piston drills with outside jet and axial water-feed machines were 233 and 254 (average) particles per cc., while the averages reported by the Chamber of Mines committee on dust sampling at Johannesburg for the first ten months of 1920 were 210 and 269 respectively. Dry-head hammer poppers with outside jet gave them 717 as compared with 724 average for 65 samples obtained in South Africa from dry-head jack hammers by Mr. H. E. Barrett, a Mines Inspector. The statement that dust counts might easily vary by as much as 100 % was unfair and inaccurate. An operator experienced in the use of a microscope should obtain results accurate to within 5 % on samples containing 500 particles per cc. Should the spot be denser the error might be higher. Dust particles, when properly in focus, had a well-defined outline, which was not the case with pit marks caused by water vapour. That matter had already been dealt with by Mr. Read—a fact which appeared to have escaped Mr. Clayton's notice. In counting, the writer used the diaphragm ruled into squares, though he did not, as Mr. Pearson stated, tie himself down to a method of counting nine or any other number of squares in each quadrant. He frequently counted spots in that way, and also by the method which he used, checking counts obtained by each method on the same spot. He found that the former method generally gave a higher average of about 4 or 5 %. He did not think the distribution of particles over the area of a spot followed any known law. He had found great variations in that respect. There was, however, always a tendency to under-estimate, for the reason that what may appear to be a particle of 3 or 5 microns in size would, when placed under a microscope of higher resolving power, show out as an aggregation of much smaller particles. That source of error was greatly intensified when the spot was heavy, and there was always a likelihood of the very small particles being masked by the larger ones and thus being missed in the count. Although they did not adopt the magnification of 225 diameters to counteract that danger, but simply because a combination of ocular and objective giving that magnification happened to be available, they thought that the higher resolving power had a certain value in exposing the very small particles. Their instrument was fitted with a mechanical traverser, therefore no difficulty was found in obtaining the diameter of the spot. The qualitative grid lines were 5 microns apart for a magnification of 200 diameters. He preferred the squared grid for counting, for the reason that, the squares being comparatively small unit areas, the mechanical business of counting was facilitated, resulting in less chance of individual particles being counted twice, or possibly being missed altogether, and also involving considerably less eye strain for the operator. Mr. Pearson's design for a counting diaphragm would be open to the same objection as the angular method sometimes used by the South African operators. That method permits of good counts being easily and quickly made as long as the number of particles did not exceed 300 per cc. on a 5 cc. sample ; above that the counting became a tedious operation and a heavy strain upon the eyes. When counting samples of air containing upwards of 600 particles per cc., and using a diaphragm ruled into squares, there were seldom more than 8 particles per square, which number was not too great to be kept clearly defined without possibility of double counting and eye strain. That would not be the case if the angular method were used.

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